Tesla's Wireless "World System"

To Turn Earth into One Gigantic Dynamo

The Wireless

1. Teleprinting, making it possible to see any object at any distance.
2. Universal twenty-four-hour daylight by wireless illumination.
3. Instantaneous transmission of typewritten or handwritten characters all over the world.

Wonders That Tesla's "World System" May Perform.

4. Communication with Mars.
5. Operation of all manufacturing and transportation machinery.
6. Every clock and watch in the world set and regulated by wireless at the same time each day.
7. Universal telephony, making it possible to speak to any distance.
8. A perfect government secret signal service by exclusive wireless wires.
9. Simultaneous operation of all stock exchanges throughout the world.

Reproduction of drawings and fine prints at any distance.

Absolutely exact reproduction of drawings and telegraphy and telephony.

How Man May Derive His Power in the Ages Still to Come.

The diagram on the opposite page illustrates Mr. Tesla's scheme for utilizing the wireless power, which he proposes to distribute to a large number of centers throughout the world, and from which power may be obtained in any part of the globe. The scheme is not only interesting because it offers a solution to the problem of obtaining wireless power, but it also provides a means of solving many practical problems.

The diagram also shows the method of transmitting the wireless power, which is accomplished by a series of transmitters placed at various points around the globe. These transmitters are connected by cables and are controlled by a central station. The transmitted power is then distributed to the various points throughout the world, where it can be used for a variety of purposes. The diagram further illustrates the use of this power for various applications such as telegraphy, telephony, and electric lighting.
The Tesla High Frequency Oscillator

By H. Winfield Secor, E.E.

Tesla, probably the highest authority in high frequency electrical engineering to-day, has not been dreaming about a Tesla tower for a few years, although we have not heard much from him, except through the daily newspapers, which now and then publish some world-startling interview describing a "marvelous" Tesla wave with which it is possible to communicate with Mars and several hundred other astounding stunts that the winner of the Nobel physics prize probably never even thought of, much less attempted to accomplish.

Most of our readers have, no doubt, seen pictures of the famous Tesla wireless tower located at Shoreham, Long Island, and which structure has involved the expenditure of a vast sum of money. From this lofty structure, which was designed in the neighborhood of 20 years ago by Dr. Tesla and his associates, there was to be propagated an electric wave of such intensity that it could charge the earth to such an extent that the effect of the wave or charge could be felt in the utmost confines of the globe.

Our front cover illustration shows the Tesla tower in theoretical operation and, in line with some of the latest statements from this marvelous man, there may be perceived several dreadnoughts being blown to atoms, which is due to the high tension electric wave sent out from this center of vast electrical activity.

Tesla, for obvious patent reasons, does not go into details just how whole fleets of a hostile navy can be destroyed in this way by means of powerful electric waves, but quite possibly he has in mind the fact that the latter can be tuned, undoubtedly, to a particular wave of certain frequency and power to accomplish this result when liberated from such a mighty station or oscillator, as is located on Long Island. Such ships as the great steel shell dreadnoughts of to-day would, of course, have a large electrical capacity and this would help in the Tesla theory which covers the transmission and reception of an electric wave of sufficient intensity to do great good or damage, as the case might be.

The illustration on the front cover of this issue shows future possibilities which may be developed on the Tesla theory as and hence it becomes evident that if this system is ever perfected and applied practically, the elevated radio energy transmitting station will have to be placed at a considerable distance inland. Again, as this wireless energy can be transmitted hundreds and even thousands of miles without any appreciable loss, according to Tesla's beliefs and statements, no disadvantage or inefficiency would be incurred by so locating the tower away from the coast; but, on the contrary, from this theory, the invading fleet of war vessels could be destroyed when they were still several hundred miles off shore. Hence, it would be impossible for them to hurl projectiles this distance. Also presumably this method of detonating the powder magazines of the war vessels could be applied to similar containers of high explosives on land, such as those carried by the heavy artillery corps of an invading army.

Further, it may be said that Tesla, all in all, does not believe in the modern Hertzian wave theory of wireless transmission at all. Several other engineers of note have also gone on record as stating their belief to be in accordance with Dr. Tesla's. More wonderful still is the fact that this scientist promulgated his basic theory of transmission a great many years ago in some of his patents and other publications. Briefly explained, the Tesla theory is that a wireless tower, such as that here illustrated and specially constructed to have a high capacity, acts as a large electric condenser. This is charged by a suitable high frequency, high voltage apparatus and a current is discharged into the earth periodically and in the form of a high frequency alternating wave. The electric wave is then supposed to travel through the earth along its surface shell and in turn to manifest its presence at any point where there might be erected a similar high capacity tower to that above described.

A simple analogy to this action is the following: Take a hollow spherical chamber filled with a liquid, such as water; and then, at two diametrically opposite points, let us place, respectively, a small piston pump, such as a bicycle pump, and an indicator, such as a pressure gauge. Now, if we suck some of the water into the pump and force it back into the ball by pushing on the piston handle, this change in pressure will be indicated on the gauge secured to the opposite side of the sphere. In this way the Tesla earth currents are supposed to act.

The patents of Dr. Tesla are basically quite different from those of Marconi and others in the wireless telegraphic field. In the nature of things this would be expected to be the case, as Tesla believes and has designed apparatus for transmission of large amounts of electrical energy, while the energy received in the transmission of intelligence is wireless amounts to but a few millivolts of an ampere in most cases by the time the current so transmitted has been picked up a thou-
millions of volts pressure. The external appearance of the Tesla generating plant and antenna support (185 feet high) are shown

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in a vertical wave system, as it has been explained and believed in, is transmitted with only a very small loss to the receiving point. In Tesla's system the energy radiated is not used, but the current is led to earth and is not transmitted by a process of condensation. The result is, the earth receives a large number of powerful high frequency electric shocks every second, and each such shock affects the entire globe in the form of a metallic tower, as will be described more in detail hereafter.

Quoting from one of Tesla's early patents on this point: "It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true coupling, and it is not to be confused with the phenomena of electrical radiation which have hitherto been observed, and which, from the very nature and mode of propagation, would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance."

He states further: "From my experiments and observations I conclude that with electromotive impulses not greatly exceeding 30,000,000 volts, the energy of millions of horsepower may be transmitted over vast distances, measured by thousands and even millions of miles, with terminations not more than 30,000 to 35,000 feet below the level of the earth; and even this comparatively small elevation will be required chiefly if the idea of economy is properly understood, or it may be considerably reduced; since, by means as have been described, practically any potential that is desired may be obtained. The current through the air strata may be rendered very small, whereby the loss in the transmission may be reduced. It will be understood that the transmitting as well as the receiving coils, transformers, or other apparatus may be in some cases movable— as, for example, when operated by vessels floating in the air, or by ships at sea."

Tesla is not an idle dreamer, as many men are inclined to believe, but back in the year 1899, he worked on some practical tests carried out in Colorado, in producing high frequency electrical discharges, the apparatus of which had never before been witnessed by man. He had applied for a patent on this invention, but until now it has not been patented properly since, to the best of our knowledge. Some of these sparks measured 100 feet in length and produced a roar like the Niagara Falls. The multitude of mighty sparks and flashes produced a discharge so terrific that no human being could stay in the building in which they took place. Some of the sparks were as thick as a man's arm and others manifested even greater intensity. They were produced by a gigantic Tesla high frequency coil with which experiments of to-day are more or less familiar in a small way. About 300 kilowatts were utilized in producing these discharges, which resembled actual lightning bolts and produced violent conflagrations. The amperage measured 800, and the voltage was up in the millions. The demonstration of these sparks, as described in Tesla's early work along this line, have been covered in previous issues of The Electrical Experimenter.

Regard the Tesla tower on Long Island and the general engineering features of same, we may refer to his patent which covers the design of the high frequency apparatus of most important elements and capable of charging the structure at several points of the mast the connection with D is to be made at or near the center, Tesla specifies, in order to secure a symmetrical distribution of the current. Otherwise the frequency is high and the flow of large volume of the apparatus might be impaired. The primary C is excited in any desired manner from a suitable source of current G, which may be an alternator or condenser, the important requirement being that the resonant condition is established; that is to say, that the terminal C is charged to the maximum pressure developed in the circuit.

The adjustments should be made with particular care when the transformer is one of great power, not only on account of economy, but also in order to avoid danger, since a suitable transformer like the one in the diagram here is capable of producing around Z in a resonating circuit as A A B B D immense electrical activities, measured by tens and even hundreds of thousands of horsepower, and in some cases, if the points of maximum pressure should be shifted below the terminal D, from small coils of fire might break out all over the world. It is possible to comprehend the instantaneous value of the energy so involved being truly astronomical. For the sake of completeness, it should be stated that the destructive action may take place with inconceivable violence. This will cease to be surprising when it is considered that the entire energy accumulated in the excited circuit (instead of requiring, as under normal working conditions, one fourteenth of the period of the transformation from static to kinetic form) may spend itself in an incomparably small space of time—several billionths of a second.

It may seem quite impossible for many of the large figures cited by Tesla with regard to the voltage and horsepower liberated or propagated when such a giant is designed. However, by referring to Fig. 3, this matter can be more readily understood. This diagram shows how a graphic curve, appearing for the first time, is to be considered. The horsepower of the former is transformed into the latter, it being passed through a circuit for the time period of one second. Now consider that instead of this 100 horsepower of energy being delivered at one stroke, in normal fashion for a period of one second, that it is hopped up or liberated in about one-fifth of a second at B. The horsepower or watts, let us say in this case, would be dissipated at a much higher intensity than was the case at C. In other words, the rate of transformation of this instance would be 300 horsepower for one-fifth of a second instead of 100 horsepower for one second.

It is considered that a Tesla current as produced by an oscillatory discharge from condensers and the like take place in a very small fraction of time, then Tesla's statement in his patent is in accordance with regard to the production of hundreds of thousands of horsepower is not so falshered. It may appear at first an impracticable, but with one of our editorial staff he has worked out the theory that the oscillator here pictured is supposed to be excited with an input of only 100 kilowatts; the average person then begins to gasp for air. An input of only 300 kilowatts! How, then, could this tower be caused to oscillate and liberate energy at the rate of hundreds of

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enclosed an air space around the boilers proper. The maximum value of this arrangement was 4½ to 1. The maximum pounds of steam generated was 12 pounds per 100 square feet of sunshine, or the equivalent to 1200 pounds per brake horse power. The best hours' run developed, at atmospheric pressure, 1,442 pounds of steam. Hence pounds steam per brake horse power) the maximum output for an hour was 55.5 horse power (about ten times better than any previous results). This means 61 brake horse power per acre of land occupied by the plant. Moreover, no marked reduction in the horsepower produced was noticeable in the early hours of the morning or in the late hours of the afternoon.

The engineers of the concern which made these tests at McAdoo recommended that such solar plants were feasible and practical and that undoubtedly they would be a very good thing in such arid regions for irrigation purposes. One argument brought against them, however, was that the power would not be available in cloudy weather, but then the irrigation would not be necessary.

Thus the fight goes on between Dame Nature and the scientists. Whether we shall ever have an efficient solar boiler and engine is a problem worth thinking about and a very interesting one at that, as we possess no greater source of natural energy to be had without taxation or special levies from some money-grabbing coal, oil, or other brawn, than that of the sun. Some day we may be able to derive all necessary light and power, for our homes at least, by means of a solar-electric plant located on the roof, and who shall say that we must be taxed for utilizing such energy?

THE TESLA HIGH FREQUENCY OSCILLATOR.

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thousands of horsepower? However, this figures out better than might be expected on hand. With an input of 900 kilowatts at the Tesla coil primary existing such a structure and considering that this amount of energy is discharged through the earth in six thousandths (0.0006) of a second, then the rate of liberation of the energy will be 120,000 horsepower.

Many perhaps would doubt that even with their usual high frequency sets, where a high frequency amperage placed in the high frequency circuits may register but a mere fraction of current, yet an average maximum for the oscillation passing through the circuit may and often does reach the value of over 115 amperes. As the amplitudes of each successive high frequency alternation is less than the one preceding it, of course the first oscillations are much higher than the average amplitude just mentioned. Consequently the peak value of the current which flows through the electrode and into a person (who may happen to be connected in series with the 115 candlepower lamp for demonstration purposes) may reach a very much higher figure than 115 amperes.

A tiny electric lamp on the front porch and another on the back porch, left burning all night, will keep night prowlers and burglars away, because no thief cares to take a chance in the light. They need darkness and black shadows for their protection. One two-candlepower lamp for the front porch and another on the back porch can be turned on all night for a few cents a month, which is certainly cheap burglar insurance.

Go to page 615.
Illustrating the Method by Which Electric Power is Conducted From One Place to Another Without Wires. The Balloons Act as the Poles of the Dynamos and the Current Flashes Across Through the Raredfied Air.

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<th>Diagram Illustrating the Principle of Tesla's Transmitter of Electric Power</th>
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Without loss through the air direct to power point, where it is used to supply the apparatus of one of the expeditions. The amount of power which can be transmitted through the air is limited by the laws of electricity and the intensity of the magnetic field which can be produced in the vicinity of the send and receive points.

**Diagram Illustrating the Principle of Tesla's Transmitter of Electric Power**

- **A.** Power coil.
- **B.** Rectangular coils.
- **C.** Transformer.

**Six Polar Expeditions.**

Mr. Wellcome's Polar Expedition.

Mr. Wellcome, who has always been interested in the development of wireless telegraphy, is sponsoring an expedition to the North Pole. The expedition will be equipped with Tesla's transmitter and receiver to demonstrate the feasibility of wireless communication in the polar regions.

Mr. Wellcome's Polar Expedition:

- **Object:** To test the practicality of wireless telegraphy in the polar regions.
- **Equipment:** Tesla's transmitter and receiver.
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The principle that allows us to give this talk involves the use of Tesla's apparatus. The apparatus works on the principle of oscillation, which means that power can be transmitted without wires. The system involves the use of alternating current, which is generated by the transmitter and transmitted through the air. The receiver then picks up the current and converts it back into usable power.

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U. S. Blows Up Tesla Radio Tower

SUSPECTING that German spies were using the big wireless tower erected at Shoreham, L. I., about twenty years ago by Nikola Tesla, the Federal Government ordered the tower destroyed and it was recently demolished with dynamite. During the past month several strangers had been seen lurking about the place.

Tesla erected the tower, which was about 185 feet high, with a well about 100 feet deep, for use in experimenting with the transmission of electrical energy for power and lighting purposes by wireless. The equipment cost nearly $200,000.

The late J. P. Morgan back up Nikola Tesla with the money to build this remarkable steel tower, that he might experiment in wireless even before the public knew of Marconi. A complete description, revised and rewritten by Dr. Tesla himself, of this unique and ultra-powerful radio plant was given in the March, 1916, issue of THE ELECTRICAL EXPERIMENTER. Everyone interested in the study of high frequency currents should not fail to study that dis-course as it contains the theory of how this master electrician proposed to charge this lofty antenna with thousands of kilowatts of high frequency electrical energy, then to radiate it thru the earth and run ships, factories and street cars with "wireless power."

Most of our readers have, no doubt, read about the famous Tesla wireless tower, which structure involved the expenditure of a vast sum of money and engineering talent. From this lofty structure, which was designed some 20 years ago by Dr. Tesla and his associates, there was to be propagated an electric wave of such intensity that it could charge the earth to such a potential that the effect of the wave or charge could be felt in the utmost confines of the globe.

Further, it may be said that Tesla, all in all, does not believe in the modern Hertzian wave theory of wireless transmission at all. Several other engineers of note have also mulligated his basic theory of earth current transmission a great many years ago in some of his patents and other publications. Briefly explained, the Tesla theory is that a wireless tower, such as that here illustrated and specially constructed to have a high capacity, acts as a huge electric condenser. This is charged by a suitable high frequency, high voltage apparatus and a current is discharged into the earth periodically and in the form of a high frequency alternating wave. The electric wave is then supposed to travel thru the earth along its surface shell and in turn to manifest its presence at any point where there might be erected a similar high capacity tower to that above described.

A simple analogy to this action is the fol-lowing: Take a hollow spherical chamber filled with a liquid, such as water; and then, at two diametrically opposite points, let us place, respectively, a small piston pump, such as a bicycle pump, and an indicator, such as a pressure gage. Now, if we suck some of the water into the pump and force it back into the ball by pushing on the piston handle, this change in pressure will be indicated on the gage secured to the opposite side of the sphere. In this way the Tesla earth currents are supposed to act.

The patents of Dr. Tesla are basically quite different from those of Marconi and others in the wireless telegraphic field. In the nature of things this would be expected to be the case, as Tesla believes and has designed apparatus intended for the transmission of large amounts of electrical energy, while the energy received in the transmission of intelligent wireless messages amounts to but a few millionths of an ampere in most cases by the time the current so transmitted has been picked up a thousand miles away. In the Hertzian wave system, as it has been explained and believed in, the energy is transmitted with a very large loss to the receptor by electro-magnetic waves which pass out laterally from the transmitting wire into space. In Tesla's system the energy radiated is not used, but the current is led to earth and to an elevated terminal, while the energy is transmitted by a process of conduction. That is, the earth receives a large number of powerful high frequency electric shocks every second, and these act the same as the pump piston in the analogy.

Quoting from one of Tesla's early patents on this point: "It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true conduction and is not to be confounded with the phenomena of electrical radiation, which have heretofore been observed, and which, from the very nature and mode of propagation, would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance."
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Quoting from one of Tesla's early patents on this point: "It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true conduction and is not to be confounded with the phenomena of electrical radiation, which have heretofore been observed, and which, from the very nature and mode of propagation, would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance."
Three fundamental principles underlying the operation of Tesla's global wireless telecommunications system are:

1. Low frequency alternating current can be transmitted through the inhomogeneous earth with low loss because the net resistance between antipodes of the earth is considerably less than 1 ohm. "Nikola Tesla and the Diameter of the Earth: A Discussion of One of the Many Modes of Operation of the Wardenclyffe Tower," K. L. Corum and J. F. Corum, Ph.D. 1996] The electrical displacement takes place predominantly by electrical conduction through the more conductive regions, i.e., oceans, lakes, metallic ore bodies and similar subsurface structures. Electric displacement is also by means of electrostatic induction through the more dielectric regions such as quartz deposits and other non-conducting minerals.

2. Low frequency high voltage alternating current can be transmitted through the atmosphere with low loss. The electric displacement takes place by a) electrostatic induction, b) electrical conduction, or a combination of these two.

3. The earth possesses a naturally existing negative charge or DC electrostatic potential, on the order of 400,000 volts, with respect to the conducting region of the atmosphere beginning at an elevation of about 50 kilometers, and near the earth's surface there is a ubiquitous downward directed E-field of about 100 V/m. The Tesla coil transmitter creates a disturbance in this charge, which manifests itself as an annular distortion of the background electric field around it.

My experiments . . . in Colorado showed that at a height of 1 mile it is plenty enough rarefied to break down under the stress and conduct the current to the distant points. . . . My patent says that I break down the atmosphere "at or near" the terminal. If my conducting atmosphere is 2 or 3 miles above the plant, I consider this very near the terminal as compared to the distance of my receiving terminal, which may be across the Pacific. . . . I have constructed and patented a form of apparatus which, with a moderate elevation of a few hundred feet, can break the air stratum down. You will then see something like an aurora borealis across the sky, and the energy will go to the distant place. . . . An apparatus which permits displacing a certain quantity of electricity in the terminal—we shall say so many units—will produce an electric potential at a distance of 5 miles, and the fall of electric potential per centimeter will be equal to the quantity of electricity divided by the square of the distance. . . . Now, I have satisfied myself that I can construct plants in which I may produce, per kilometer of the atmosphere, electric differences of potential of something like 50,000 or 60,000 volts, and at 50,000 or 60,000 volts that atmosphere must break down and will become conductive. . . .

The earth is 4,000 miles radius. Around this conducting earth is an atmosphere. The earth is a conductor; the atmosphere above is a conductor, only there is a little stratum between the conducting atmosphere and the conducting earth which is insulating. . . . Now, you realize right away that if you set up differences of potential at one point, say, you will create in the media corresponding fluctuations of potential. But, since the distance from the earth's surface to the conducting atmosphere is minute, as compared with the distance of the receiver at 4,000 miles, say, you can readily see that the energy cannot travel along this curve and get there, but will be immediately transformed into conduction currents, and these currents will travel like currents over a wire with a return. The energy will be recovered in the circuit, not by a beam that passes along this curve and is reflected and absorbed, . . . but it will travel by conduction and will be recovered in this way.
Under ideal no-load conditions the movement of electrical energy throughout the system appears to be totally reactive and only when electrical loads are present does real power flow.

I understand that Nikola Tesla proposed a wireless transmission system that used electrical conduction instead of radio waves. This method was put forth in his U.S. Patents No. 645,576 and 649,621 where he mentions a 15-mile high antenna wire. It seems to me that the obstacles to building such an elevated structure would be insurmountable, as all existing materials would self-destruct from their own weight, although a fiber of carbon nanotubes might come close. Add to this the shearing forces and whipping stresses by existing winds up to 80,000 ft. and no, the materials to build such "antennas" which did not exist in Tesla's time, still do not exist. What could he have been thinking?

The reference to, "maintaining terminals at elevations of fifteen miles or more above the level of the sea" is followed by the following self-explanatory statement.

Through my discoveries before mentioned and the production of adequate means, the necessity of maintaining terminals at such inaccessible altitudes is obviated . . .
Tesla expanded upon this assertion in the 1916 interview.

Counsel

I have read in some of your writings that you went to Colorado to further experiment with certain apparatus which you had tested to your own satisfaction at sea level. . . . was that demonstration undertaken in Colorado for the purpose of getting the higher altitude of the air?

Tesla

No, it was nothing of the kind. I simply went there because in Colorado my system of power transmission was introduced. All around the plants in the mountains, my three-phase system, and the induction motors were employed. . . . I had friends there who were only too delighted to give me all the power I wanted, and not charge anything for it. . . . My experiments [on Houston Street] showed that at a height of 5 miles the air was in conduction to transmit the energy in this way, but my experiments in Colorado showed that at a height of 1 mile it is plenty enough rarefied to break down under the stress and conduct the current to the distant points.

I have to say here that when I filed the applications of September 2, 1897, for the transmission of energy in which this method was disclosed, it was already clear to me that I did not need to have terminals at such high elevation, but I never have, above my signature, announced anything that I did not prove first. That is the reason why no statement of mine was ever contradicted, and I do not think it will be, because whenever I publish something I go through it first by experiment, then from experiment I calculate, and when I have the theory and practice meet I announce the results.

At that time I was absolutely sure that I could put up a commercial plant, if I could do nothing else but what I had done in my laboratory on Houston Street; but I had already calculated and found that I did not need great heights to apply this method. My patent says that I break down the atmosphere "at or near" the terminal. If my conducting atmosphere is 2 or 3 miles above the plant, I consider this very near the terminal as compared to the distance of my receiving terminal, which may be across the Pacific. That is simply an expression. I saw that I would be able to transmit power provided I could construct a certain apparatus -- and I have, as I will show you later. I have constructed and patented a form of apparatus which, with a moderate elevation of a few hundred feet, can break the air stratum down. You will then see something like an aurora borealis across the sky, and the energy will go to the distant place. . . .
TESLA WIRELESS TRANSMISSION THEORY

The wireless method Tesla planned to use at Wardenclyffe involves an electric current flowing through the earth between a Tesla coil transmitter and a Tesla coil receiver. Both the transmitter and receiver would be built the same way, with a powerful Tesla coil located inside each of the tower structures. In the case of Wardenclyffe the second plant was to be constructed on the southern coast of England, possibly in Cornwall.

The atmospheric conduction method depends upon the passage of electrical current through both the earth and the atmosphere.

"The earth is 4,000 miles radius. Around this conducting earth is an atmosphere. The earth is a conductor; the atmosphere above is a conductor, only there is a little stratum between the conducting atmosphere and the conducting earth which is insulating. . . . Now, you realize right away that if you set up differences of potential at one point, say, you will create in the media corresponding fluctuations of potential. But, since the distance from the earth's surface to the conducting atmosphere is minute, as compared with the distance of the receiver at 4,000 miles, say, you can readily see that the energy cannot travel along this curve and get there, but will be immediately transformed into conduction currents, and these currents will travel like currents over a wire with a return. The energy will be recovered in the circuit, not by a beam that passes along this curve and is reflected and absorbed, . . . but it will travel by conduction and will be recovered in this way. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, pp. 129-130]

The electric current through the earth is balanced by an equivalent electrical displacement of the opposite sign through the space above it. This displacement can be achieved by means of electrical conduction through the atmosphere without violating any of the known laws of physics. With energy transmission by true electrical conduction, a very high voltage on the order of 15 million volts is needed on both of the elevated terminals to break down the insulating air around and above each plant. The ionization of the atmosphere directly above the elevated terminals is facilitated by a vertical ionizing beam of ultraviolet radiation that leads to the formation of a plasma high-voltage electrical transmission line. The upper troposphere between the transmitter and the receiver is available for a conductor by inducing the plasma state within that region. This is the “aurora” effect described by Tesla in the 1916 interview.

"I have constructed and patented a form of apparatus which, with a moderate elevation of a few hundred feet, can break the air stratum down. You will then see something like an aurora borealis across the sky, and the energy will go to the distant place." [NTAC, p. 110]

The end result is a flow of true conduction currents between the two elevated terminals by a path up to and through the troposphere, and back down to the other facility. To learn more about this mode of operation read the paper "Nikola Tesla On
Wireless Energy Transmission, with additional comments by Henry Bradford and Gary Peterson

In addition to the atmospheric-conduction method the Tesla coil transmitter design is also adaptable to another method that Tesla had for wireless transmission called "earth resonance." Comparing Tesla's patents covering his wireless system using the earth-resonance method and those covering the atmospheric-conduction method reveals that both the basic transmitting and receiving apparatus are identical. Both consist of large Tesla coils connected to the earth and to high-voltage elevated terminals. (It is important to note that a single earth-resonance Tesla coil transmitter can be made to perform exactly as intended without any additional stations being present. In this case the earth itself overrides the requirement that one or more additional stations be placed into operation.)

The differences between the two methods are in the potential that is required at the TC transmitter's elevated terminal, and also in the operating frequency. For atmospheric conduction about 15 million volts is needed. For earth resonance the elevated terminal has to be charged up to about 100 million volts! As for frequency, the usable base frequency spectrum is about the same for both types of system, say 1,000 to 35,000 cycles per second (1-35 kHz). An atmospheric conduction system can operate at any arbitrarily selected frequency in this region. With an earth resonance system it is compulsory that it operate on some harmonic of the fundamental earth-resonance frequency, reported by Tesla as being about 12 Hz.

By the way, there is a misconception among many Tesla researchers that he intended to transmit electric power through the Schumann or earth-ionosphere cavity. While Tesla definitely spoke of exciting a terrestrial resonance mode, he was not talking about exciting a Schumann resonance. The terrestrial resonance mode that he apparently excited in 1899 at Colorado Springs is referred to by some as an "earth resonance mode," which are different from the Schumann resonance modes. Also remember that Tesla made a distinction between electrical energy transmission by atmospheric conduction and electrical energy transmission using earth resonance principles.

"... In one the ionizing of the upper air would make it as good a conductor of electricity as a metal. In the other the power would be transmitted by creating "standing waves" in the earth by charging the earth with a giant electrical oscillator that would make the earth vibrate electrically in the same way a bell vibrates mechanically when it is struck with a hammer. . . ." ["Tesla Cosmic Ray Motor May Transmit Power 'Round' Earth," Brooklyn Eagle, July 10, 1932, John J. A. O'Neill]

One final note, the earth possesses a naturally existing negative charge with respect to the conducting region of the atmosphere beginning at an elevation of about 50 kilometers. The potential difference between the earth and this region is on the order of 400,000 volts. Near the earth's surface there is a ubiquitous downward directed E-field of about 100 V/m. In LIGHTNING PROTECTOR, May 6, 1916, U.S. Patent 1,266,175, May 14, 1918 Tesla referred to this charge as the “electric niveau" or electric level.

"A point of great importance would be first to know what is the capacity of the earth? and what charge does it contain if electrified? Though we have no positive
evidence of a charged body existing in space without other oppositely electrified bodies being near, there is a fair probability that the earth is such a body, for by whatever process it was separated from other bodies—and this is the accepted view of its origin—it must have retained a charge, as occurs in all processes of mechanical separation. If it be a charged body insulated in space its capacity should be extremely small, less than one-thousandth of a farad. But the upper strata of the air are conducting, and so, perhaps, is the medium in free space beyond the atmosphere, and these may contain an opposite charge. Then the capacity might be incomparably greater. In any case it is of the greatest importance to get an idea of what quantity of electricity the earth contains. It is difficult to say whether we shall ever acquire this necessary knowledge, but there is hope that we may, and that is, by means of electrical resonance. If ever we can ascertain at what period the earth's charge, when disturbed, oscillates with respect to an oppositely electrified system or known circuit, we shall know a fact possibly of the greatest importance to the welfare of the human race. I propose to seek for the period by means of an electrical oscillator, or a source of alternating electric currents. . . . ["On Light and Other High Frequency Phenomena," Franklin Institute, Philadelphia, February 1893, and National Electric Light Association, St. Louis, March 1893.]

Tesla coil earth resonance transmitters create a local disturbance in the earth's charge that manifests itself as an annular deviation in the strength of the background electric field. This disturbance moves away from the transmitter and diminishes in intensity as the distance from the transmitter increases. A sufficiently powerful transmitter produces a field distortion that propagates to the antipode at which point the energy is reflected back towards its point of origin. The transmission of electrical energy across the entire globe and its reflection all the way back to its source is the basis of Tesla's earth resonance method. While the atmospheric conduction method requires that both transmitting and receiving apparatus be placed into operation, a properly tuned and sufficiently powerful earth resonance transmitter, on the other hand, can be made to operate exactly as intended without any man-made Tesla coil receivers being activated. The earth itself fulfills the important requirement that a synchronized receiver be present.

To conclude this section, the two fundamental principles behind the operation of Tesla's system are:

1. Low frequency alternating current can be transmitted through the earth with low resistive loss due to the fact that the resistance between antipodes of the earth is considerably less than 1 ohm.

2. Low frequency high voltage alternating current can be transmitted through the atmosphere with low loss. The electrical displacement takes place by a) electrostatic induction, b) electrical conduction, or a combination of these two.

**Wireless Energy Transmission for the Amateur Tesla Coil Builder**

One question to be answered about Tesla's wireless system is whether the energy is being carried from the transmitter to the receiver by ordinary radio waves or if some other mechanism is involved. We are speaking here of scaled-down versions
of Tesla’s wireless system such might be assembled by the typical Tesla coil experimenter. The operational power levels involved are assumed to be insufficient to excite earth resonance or result in massive atmospheric ionization in the vicinity of the oscillators. No provisions are made for the generation of vertical ionizing beams originating at the elevated terminals and projecting up to an elevation of say 8 km where conductivity can more easily be imparted to the air.

Nine Proposed Mechanisms

Regarding the transmission of electrical energy from a Tesla coil transmitter to a Tesla coil receiver, seven possible mechanisms have been identified that are available according to present electromagnetic field theory. The first three are far-field electromagnetic radiation or ordinary radio waves, mutual induction, and mutual capacitance. The fourth is the Goubau or G-line waveguide transmission line model presently being advanced by William Beaty. There may be aspects of the physics behind the G-line that are not fully understood. The fifth is an alternative mechanism involving ordinary radio waves produced in the far-field zone as a result of ground currents propagating to a great distance from operating Tesla coil transmitters. Henry Bradford is presently developing this hypothesis. The sixth mechanism is the propagation of an ion-acoustic wave in the intervening space between the two elevated terminals. The seventh mechanism is the modulation of natural plasma that exists because of the electrical potential gradient between the earth’s surface and the conducting region of the atmosphere beginning at about 50 kilometers.

An eighth proposed mechanism considers the transmitter and receiver as being “self-referencing” by means of virtual electrical grounds, a theoretical concept developed by Eric Dollard and others in the 1980s.

The ninth proposed mechanism is what might be called "electrostatic induction."

Far-field electromagnetic radiation or ordinary radio waves

Ordinary radio waves can be excluded because field measurements taken on actual Tesla coil transmitters demonstrate that when these devices are in a higher state of refinement they are very inefficient in terms of the production of electromagnetic radiation. There is insufficient signal strength to account for the amount of energy received in the far-field zone.

Mutual induction

Energy transmission by "mutual induction" can also be excluded because the magnetic field density falls off too rapidly to account for amount of energy received in the far-field zone.

Mutual capacitance or displacement current

The elevated terminal of a Tesla-coil transmitter functions as a capacitor plate. Opposite to this plate is every other electrically conducting body to which it is connected, including the earth and, in some cases, the receiving transformer's elevated terminal. The transmitter's elevated terminal serves two purposes: first, it
acts as a charge reservoir in relation to the earth's surface in the immediate vicinity of the transmitter; second, it is one of two electrodes, the other electrode being the receiving facility's elevated terminal. The transfer of energy between a Tesla coil transmitter and the requisite Tesla coil receiving transformer is by electrical conduction between the two respective ground terminals. For distances up to about 1/2 wavelength the propagation of energy between the respective elevated terminals is the result of displacement currents, exactly like the transfer of electrical energy between the plates of a conventional capacitor in an AC circuit. This explanation is fine for distances up to about 1/2 wavelength, but in general the electric field intensity follows an inverse square, and diminishes rapidly with distance. Therefore, energy transmission by "mutual capacitance" can be excluded because when the two elevated terminals are separated by more than one-half of a wavelength of the applied current they are, for practical purposes, electrically decoupled.

The Goubau or G-line waveguide transmission-line model

This explanation is a strong candidate. A Tesla coil transmitter consisting of a high voltage, pulse-driven, end-loaded resonator launches a transmission-line wave, similar to the Zenneck Surface Wave, in the form of earth currents and a charge-coupled electromagnetic field.

The Bradford Hypothesis

This explanation is also in the running. The basic idea is that the earth currents and charge-coupled electromagnetic field associated with Tesla coil transmissions gradually decouple from the associated charge carriers and become ordinary radio waves as a function of the distance from the transmitter. Mr. Bradford states, “I do not believe that the theory for it has been worked out, but in principle it is a straightforward application of electromagnetic theory.”

Electrostatic or magneto-hydrodynamic plasma wave model

In operation a radio-frequency current is applied to each of the two resonators creating, at each location, an oscillating magnetic field. In turn, the oscillating magnetic field induces an oscillating electric field. The oscillating electromagnetic field creates a weak to highly ionized plasma in the vicinity of each resonator, depending on the amount of power applied to the oscillation transformer primary. The volume of the ionized region is proportional to the peak energy of the oscillation. If the currents in the two resonators have a 180deg phase relationship with each other, then conditions are favorable for interconnection of their respective magnetic fields. In addition to the inductively coupled discharge created plasma, conditions also exist for the creation of capacitively coupled discharge plasma between the two respective elevated terminals. These would be either electrostatic waves or more likely magneto-hydrodynamic waves, assuming the presence of inter-connected magnetic field lines. The transfer of energy between a Tesla coil transmitter and the requisite Tesla coil receiving transformer is by electrical conduction through the earth between the two respective ground terminals, and also through artificially created weakly ionized plasma between the two elevated terminals. For a high-power system, coupling between the elevated terminals is by electrical conduction through highly ionized plasma. The two electrodes act as high voltage discharge
terminals for the formation of capacitively coupled discharge plasma with the electrical interconnection taking place through the upper level atmosphere. The ionization of the denser atmosphere directly above the elevated terminals is facilitated by the use of an ionizing beam of ultraviolet light to form what might be called a high-voltage plasma transmission line.

**Modulation of naturally existing plasma model**

The entire earth possesses a naturally existing negative charge or DC electrostatic potential with respect to the conducting region of the atmosphere beginning at an elevation of about 50 kilometers. The potential difference between the earth and this region is on the order of 400,000 volts. Near the earth's surface there is a ubiquitous downward directed E-field of about 100 V/m. In operation, a grounded Tesla coil transmitter creates a local disturbance in this charge. The disturbance manifests itself as an annular distortion of the background electric field around the transmitters ground terminal. At a point in time when a measurement of the e-field component of the EM field at the ground terminal should show zero volts above the background potential, other measurements should show it rising in intensity until a point 1/4 wavelength (1/4 λ) away from the ground terminal is reached (axial projection). From there the e-field should diminish in intensity until, at 1/2 wavelength from the terminal, it again shows zero. At a measurement point approximately one wavelength away from the ground terminal, an induced e-field once again should begin to emerge above the average background field level, again increasing in intensity until a second maxim is reached at 1 1/4 wavelengths away from the oscillator. It is possible that measurements would reveal a zero crossing to a relative potential of the opposite sign. With a sufficiently powerful transmitter this phenomenon would be expected to repeat itself over and over until the antipode is reached, at which point reflection would take place and the transmitted energy would begin to travel back to its point of origin in the reverse direction. With the proper selection of operating frequency constructive interference with the outgoing wave will take place.

**Virtual ground model**

The transmitter and receiver are viewed as being “self-referencing” through the establishment of virtual electrical grounds comprised by the two elevated terminals. The system would use earth resonance to circumvent the Newtonian law of action and reaction. “In this arrangement energy is continuously bounced back and forth between the earth and the reflecting capacitance at a rate tuned to a natural rate of the earth.” [Eric Dollard] Alternatively, circumvention of Newton’s Third Law would be due to electrodynamic force interactions between heavy ions and electrons, known as the anomalous cathode reaction force. [P.N. and A.N. Correa]

"Electrostatic induction"

For distances beyond about 1/2 wavelength the propagation of energy between the respective elevated terminals is the result of what might be called “electrostatic
induction” somewhat like the transfer of electrical energy between the two plates of a capacitor in an AC circuit. This is a proposed mechanism by which the two distant elevated terminals might be electrically coupled together in a manner similar to mutual capacitance, but at distances greatly exceeding 1/2 wavelength. Tesla used the term electrostatic induction to describe the behavior capacitors, or more generally, the electrical coupling of two or more conducting surfaces that are separated by one form or another of dielectric. This term appears in Tesla’s “SYSTEM OF TRANSMISSION OF ELECTRICAL ENERGY (U.S. Patent No. 645,576, dated March 20, 1900) and elsewhere.

“In some cases when small amounts of energy are required the high elevation of the terminals, and more particularly of the receiving-terminal D' may not be necessary, since, especially when the frequency of the currents is very high, a sufficient amount of energy may be collected at that terminal by electrostatic induction from the upper air strata, which are rendered conducting by the active terminal of the transmitter or through which the currents from the same are conveyed.”

Notes:

In the cases of mutual capacitance, the Goubau-line model, the two plasma wave models, the virtual ground model, and electrostatic induction it is an absolute requirement that both the Tesla coil transmitter and the terrestrial Tesla coil receiver be very well connected to the earth’s subsurface, allowing them to be coupled together by electrical conduction through the earth between their ground terminals.

It is quite conceivable that it will be found the best explanation for the long-distance transmission of electrical energy between a Tesla transmitter and receiver is a combination of two or more of the above-proposed mechanisms.
Historical Problems

Tesla described his wireless transmission method by three important characteristics:

- It did not use electromagnetic radiation.
- It operated through the earth or water.
- The mechanism of transmission is an electric current - not radiation.

Modern analysts, both those who believe Tesla had discovered something new and those who believe he was mistaken in his observations, see Tesla's transmission method the same as present day broadcast radio technology. The broadcast model assumes that there is an antenna propagating electromagnetic waves omnidirectionally into the air. The Tesla supporters propose many ingenious, but implausible, schemes that would account for Tesla's claims for his wireless system. The Tesla opponents simply point out that according to electromagnetic theory, Tesla's ideas are impossible. Both groups are incorrect in thinking that his wireless method is the same as the broadcast technology used today.

Anachronistic interpretation - applying the assumptions of today's electrical theories to Tesla's original turn of the century researches - is only half the problem of understanding the inventor's wireless method. The situation is further complicated by the similar sounding descriptions Tesla gave to his earlier and later transmission techniques.

In his early work, Tesla attempted electronic transmission by electrifying the atmosphere. This is the case in his patent entitled Method of Intensifying and Utilizing Effects Transmitted Through Natural Media, #685,953, applied for in June 1899. In this patent, he proposes a very powerful transmitter to ionize atmospheric gases and, by that, create a conductive path between the transmitter and receiver through which a current could be sent. Later, when Tesla disclosed his through-the-earth, and through water, transmission with essentially the same type of apparatus and operating at ELF frequencies, modern authorities have assumed that Tesla was mistaken about his method of propagation and was really witnessing earth-ionosphere cavity resonance at Schuman frequencies. More recent scholarship, however, has shown that that Tesla was aware of the differences between conventional wireless transmission methods and the technology he was developing.

Tesla was more than an engineer of conventional methods. He was an electrical researcher who investigated fundamental issues of the science. It will be shown that the three characteristics of Tesla's wireless transmission system describe an electrostatic wireless method that used the earth as a conductor and transmitted displacement currents. At moderate energy levels, the system could be used for communication. At greater levels, power could be sent by wireless.
Non-Hertzian Transmission

During 1899 - 1900, Tesla set up a laboratory in Colorado Springs to investigate wireless signal transmission. It was during this period he discovered that a properly configured receiver could detect waves, initiated by lightning strikes, propagating through the earth. Many details about the apparatus for generating and receiving electrical signals (such as tuned resonant circuits that were recognized in 1943 by the Supreme Court as the basis of commercial radio designs) are given in his writings, but he never directly reveals the physics behind the mode of propagation. Tesla does point toward his novel transmission technique when he notes that his transmission method is "the diametrical opposite of a transmitting circuit typical of telegraphy by Hertzian or electromagnetic radiations." This claim alone indicates a technology different from the transmission technology of today.

One of his early lectures on evacuated tube illumination provides a good example of physical effects he was using. Tesla describes a setup for illuminating bulbs. It consists of two plates on either side of the bulbs. The plates are connected to a transformer driven by an oscillator. The two plates are similar to a capacitor and the electrical activity between them is like the electrostatic field between two capacitor plates.

As he described it, an evacuated bulb was place between the electrodes:

... when we excite luminosity in exhausted tubes..., the effect is due to the rapidly alternating electrostatic potential; ... the medium is harmonically strained and released.

He also noted:

It might be thought that electrostatic effects are unsuited for such action at a distance. ... It is true that electrostatic effects diminish nearly with the cube of distance from the coil, whereas electromagnetic inductive effects diminish simply with distance. But when we establish an electrostatic field of force, the condition is very different, for then, instead of the differential effect of both the terminals, we get their conjoint effect.

To make sure that the difference between the type of fields he intended and those of Hertz was understood he explained:

As the term electrostatic might imply a steady electric condition, it should be remarked, that in these experiments the force is not constant, but varies... When two conducting bodies are insulated and electrified, we say that an electrostatic force is acting between them.

Tesla's emphasis on the non-Hertzian nature of his signaling process, particularly when taken within the context of his work with electrostatics, indicates the mode of propagation involves similar electrostatic effects between a transmitter and receiver. As he often insisted, this mode of transmission differs significantly from that of Hertzian waves in that this one is a form of conduction:

So far, I have considered principally effects produced by a varying electrostatic force in an insulating medium, such as air. When such a force is acting upon a conducting body of measurable dimensions, it causes within the same, or on its surface, displacements of the electricity, and gives rise to electric currents.
Also:

Some enthusiasts have expressed their belief that telephony to any distance by induction through the air is possible. I cannot stretch my imagination so far, but I do firmly believe that it is practicable to disturb by means of powerful machines the electrostatic condition of the earth and thus transmit intelligible signals and perhaps power.9

Tesla believed that the earth was not just a sink into which electrical energy can be poured, but that it is a reservoir of charge. The capacity of the earth is determined by the standard formula for the capacitance of an isolated sphere of radius R:

\[ C = 4\pi\varepsilon_0 R \]

For the earth, this works out to 708 microfarads.10

Tesla's idea was that his high power transmitter he could cause the earth's charge to oscillate and that these oscillations could be detected anywhere on the globe. He further noted that these oscillations were changes in pressure, "the energy will be economically transmitted and very little power consumed so long as no work was done in the receivers."11

To differentiate Tesla's wireless method from contemporary understanding of the technique, and from the misunderstandings arising from the chronology of Tesla's research into the nature of electrical communication, his method can be contrasted with modern patents for electrostatic submarine communication and the inventor's earlier work in this field.

**Contemporary Patents**

L. Gilstrap's patent for an Electrostatic Communication System, #3,964,051, issued June 15, 1976, describes a device consisting of two concentric conducting spheres (#26 & #28) separated by a dielectric layer to form a monopole radiator for electrostatic waves.

The patent states that "longitudinal electrostatic or capacitive waves, also called scalar or polarization waves because of their relationship to the Maxwell wave equations" are the means of propagation but the patent does not explain how these waves differ from conventional forms of electromagnetic radiation. It simply states that as the spheres are subject to voltages of opposite polarity the "outer sphere then appears as an ideal monopole radiator to the external dielectric medium, in this case water."12

In this configuration, electric field is confined to the region between the two conducting spheres of the transmitter. Little energy, if any, is available to stress the external dielectric medium, the water.

P. Curry's patent for an Underwater Electric Field Communication System, #3,265,972, issued August 9, 1966 proposes a radiator of a different configuration and presents a detailed discussion of communication by electrostatic induction.

Curry states:

The antenna system for an electromagnetic emission into space circulates energy in accordance with the laws governing...
electrical current in motion. Since the field strength produced by an antenna is proportional to the alternating currents circulating in it, its optimum structural relationships are directed to a reduction of the total antenna resistance, thus to increase the total current for a given power input to a radiator.\textsuperscript{13}

He adds:

Being a current-actuated device, such an [electromagnetic] antenna will not operate in any physical conducting medium such as water or earth.\textsuperscript{14}

While a radiator for electromagnetic emission produces its field strength by the effect of changing currents; the radiator for electrostatic emission of the type here to be described produces its field strength by the effect of changing potentials.\textsuperscript{15}

Curry proposes "the electrical potentials of the signal to be transmitted to two equal metal plates (#17 & #18) each of which is hermetically sealed within insulating material (#20 & #21) … immersed in a conducting fluid such as sea water."\textsuperscript{16} By applying a varying potential to the plates of the radiator, charge of opposite polarity accumulates on the two plates such that a charge gradient exists in the region between the radiators. The patent explains:

... a phase displacement of 90 degrees exists the wave of charge potentials induced by an alternating current signal upon the water ... and the resulting wave of charge displacements occurring in the water body between the segments.\textsuperscript{17}

The method of propagation, then, is to periodically alternate electrical charges on the two plates that will launch sinusoidal carrier waves into the medium. When one plate is positive, the other will be negative; then the first will be negative and the second positive. This action, the patent states, will create the sinusoidal waves.

In a detailed analysis of forces involved in this type of transmission Curry shows that radiators with a capacitance of .0053 microfarads operating at 100 kHz with signal generator output of 200 volts coupled with a biasing potential of 1000 volts will produce a force from its charge displacement of 26,500 dynes.\textsuperscript{18}

On the receiving side, Curry states that the charge gradient can be expected to attenuate substantially at even moderate distance from the point of transmission. As an example he notes that if a signal intensity of 10,600 dynes at the point of transmission is reduced one billion times the "standing wave of the signal energy will therefore be charged with a force differential of $1.06 \times 10^{-5}$ dynes. Each dipole in his example has a capacitance of .0053 microfarads with a system capacitance of .00265 microfarads. The voltage developed in the receiving network is .02 volts. As noted "this is substantially above the minimum requirements of signal intensity for the detection of electrical signal energies."\textsuperscript{19}

This detailed analysis, however, overlooks the important point that electrostatic waves do not propagate into the medium in the same way as electromagnetic waves. In an electromagnetic transmission system, charge is accelerated in an elevated conductor, an antenna, to launch waves omnidirectionally into the air. At a receiver, the electromagnetic waves induce a current in the antenna. The variations in the current are processed by the detection circuitry to replicate the transmitted information.

In electrostatics, it is not necessary for flux lines to detach from an antenna and close upon themselves to propagate a wave that is received at a distant point. The transmitter, in Tesla's plan, oscillates the earth's charge and the receiver is connected to that same charge reservoir. Signals are not launched, but exist as pressure variations in the earth's oscillating electric field. Because the field already exists at the point of transmission and at the point of reception, the propagation characteristics are different from electromagnetic waves.
In addition to the mode of propagation being different, what travels between the transmitter and receiver is different. In electromagnetic transmission waves are sent out that are picked up by the receiving antenna. These waves induce a current the antenna. In an electrostatic system a current passes directly between the transmitter and receiver.

This current is the same as that which exists in a capacitor, that is, it is a displacement current. In a standard inductor-capacitor-resistance circuit, when it is energized and oscillating, it is understood that the current that passes through the conductors is completed through the non-conductor of the capacitor's dielectric through a displacement current. As charge is changed on one plate of the capacitor, an opposite but equal change in charge is seen on the other plate of the capacitor. In Tesla's system the transmitter and receiver act as the capacitor plates and what passes between them is a displacement current.

Displacement current, today, is seen as something of a virtual current, something different from a "real" or conduction current that flows through a wire. Tesla, however, understood what is meant by an electrical current in the same sense as Maxwell - that "all charge is the residual effect of the polarization of the dielectric" and that "the variations of electric displacement evidently constitute electric currents." As a Maxwellian, Tesla was correct in describing his transmission system as one using true electric currents.

Tesla's wireless electrical energy transmission system differed in all three characteristics he claimed - it was not electromagnetic, it operated through the earth or water, and conveyed electrical energy by a current. Once Tesla's communication method is better understood as a new branch of electrical science that was started over 100 years ago, it will not only have an impact on terrestrial technology, but will have applications in the future for space communications.

NOTES

1 Tesla states that his transmission system is an "apparatus for submarine signaling" in Tesla, Nikola, "The True Wireless," Electrical Experimenter, May 1919, pg. 30; in the same article he also states that "transmission thru sea-water is more efficient" with his wireless method, pg. 87.


5 Tesla, Nikola, "Experiments With Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination" (1891), LPA, pg. L-42. Emphasis added.

6 LPA, pg. L-43.

7 Tesla, Nikola, "On Light and Other High Frequency Phenomena" (1893), LPA, pg. L-121.
8 LPA, L-127, emphasis added.

9 LPA, pg. L-138, emphasis added.

10 See :"The Earth as a Condenser and Its Role in Wireless Telegraphy," Scientific American Supplement, No. 1451, October 24, 1903, pg. 23248.


12 Gilstrap #3,964,051, Column 2, lines 34 - 48.

13 Curry #3,265,972, Column 1, lines 21 - 28.

14 Curry, Column 1, lines 29 - 31.

15 Curry, Column 1, lines 44 - 48.

16 Curry, Column 1, lines 49 -54.

17 Curry, Column 4, lines 8 - 38.

18 Curry, Columns 5 - 6.

19 Curry, Column 7, lines 35 - 75 to column 8 line 2.


21 Maxwell, pg. 65.
The 187-foot Wardenclyffe Tower in 1903 which stood unfinished for the next 14 years. The two-story power plant, by comparison, is in the background.
Introduction to Tesla’s Science of Energy

Thomas Valone, Ph.D., P.E.

It is a great privilege to present this amazing collection of seminal articles, some of which have never been published before, on Nikola Tesla’s science of energy. As I’m finishing my Ph.D. thesis on utilizing zero point energy, I realized that Tesla probably acknowledged the same energy reservoir when he referred to harnessing “the very wheelwork of nature.”

The visionary scientists who have contributed to this anthology offer a collective argument of what Tesla meant by that phrase. Tesla also recognized that an atmospheric and a terrestrial storage battery exists here on earth, just waiting to be tapped for the good of mankind. Therefore, this is the wheelwork of nature that we want to explore in this book.

The first section of this anthology offers some historical Niagara Falls material and biographical information about the life of Nikola Tesla with the contributions of William Terbo, the grand-nephew of Tesla, Keith Tutt, author of *The Scientist, the Madman, the Thief & Their Light Bulb*, and Dr. Andrija Puharich, whose unpublished biographical manuscript is rich with personal insights. Puharich, a Yugoslavian, also develops with great care, the background and unexpected uses for Tesla’s Magnifying Transmitter (TMT). The second section is devoted to Tesla’s wireless transmission of electrical power, as distinguished from wireless telegraphy for which he is also famous. It is surprisingly practical, even today, as the brilliant minds in this book prove. Tesla was at least a century ahead of his time, however, so people stole his ideas, left him penniless, and ignored his saintly concern for the human race. I pray that as global community consciousness expands in the 21st century, Tesla’s ideas about sharing energy with the whole world will be more understood and appreciated. The third and last section has miscellaneous articles about a few of Tesla’s less well-known inventions, including the two-rotor belted homopolar generator and an ozone generator.

Today we are faced with the consequences of the fateful decision in 1905 by J. P. Morgan to abandon Tesla’s Wardenclyffe Tower project on Long Island, once he learned that it would be designed mainly for wireless transmission of electrical power, rather than telegraphy. He is reported to have complained that he would not be able to collect money from the customer in any feasible way. This mercenary attitude by the world’s richest man forced the nation to pay for thousands of miles of transmission line wires, just so an electrical utility meter could be placed on everyone’s house. Today the U.S. Energy Association in Washington, DC trains representatives from the former Russian states how to reliably do the same in their countries.

No one, except for the few great physicists like Drs. Rauscher, Corum, Bass, and Van Voorhis found in this book, has realized that Tesla was very practical when he proposed the resonant generation and wireless transmission of useful electrical power, after returning from his experiments at Colorado Springs in 1900. For example, Professor Rauscher shows that the earth’s magnetosphere contains sufficient potential energy (at least 3 billion kilowatts) so that the resonant excitation of the earth-ionosphere cavity can reasonably be expected to increase the amplitude of natural “Schumann” frequencies, facilitating the capture of useful electrical power. Tesla knew that the earth could be treated as one big spherical conductor and the ionosphere as another bigger spherical conductor, so that together they have parallel plates and thus, comprise a “spherical capacitor.” Dr. Rauscher calculates the capacitance to be about 15,000 microfarads for the complete earth-ionosphere cavity capacitor. W.O. Schumann

1 “...it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of nature.” –Tesla addressing the Amer. Inst. of Elec. Eng., 1891
is credited for predicting the “self-oscillations” of the conducting sphere of the earth, surrounded by an air layer and an ionosphere in 1952, without knowing that Tesla had found the earth’s fundamental frequency fifty years earlier.\(^2\)

In comparison to the 3 billion kW available from the earth system, it is possible to calculate what the U.S. consumed in electricity. In 2000, about 11 Quads (quadrillion Btu) were actually used by consumers for electrical needs, which is equal to 3.2 trillion kWh. Dividing by the 8760 hours in a year, we find that only 360 million kW are needed on site to power our entire country. This would still leave 2.6 billion kW for the rest of the world! The really shameful U.S. scandal, unknown to the general public, is that out of the total electrical power generated using wire transmission (about 31 Quads), a full \(\frac{2}{3}\) is totally wasted in “conversion losses.”\(^3\) (See the Electricity Flow Chart 1999, which contains US DOE/EIA data, updating the Toby Grotz article in this book.) No other energy production system of any kind in the world has so much wastefulness. Instead of trying to build 2 power plants per week (at 300 MW each) for the next 20 years (only to have a total of additional 6 trillion kWh available by 2020), as some U.S. government officials want to do, we simply need to eliminate the \(7\) trillion kWh of conversion losses in our present electricity generation modality. Tesla’s wireless transmission of power accomplishes this goal, better than any distributed generation.

As Tesla himself said,

“In the near future we shall see a great many uses of electricity…we shall be able to disperse fogs by electric force and powerful and penetrative rays…wireless plants will be installed for the purpose of illuminating the oceans…picture transmission by ordinary telegraphic methods will soon be achieved…another valuable novelty will be a typewriter electrically operated by the human voice…we shall have smoke annihilators, dust absorbers,

\(^2\) W.O. Schumann, Z. Naturforsch, 72, p. 149-154 and 250-252, 1952, (in German)
sterilizers of water, air, food and clothing...it will become next to impossible to contract disease germs and country folk will go to town to rest and get well…”

“If we use fuel to get our power, we are living on our capital and exhausting it rapidly. This method is barbarous and wantonly wasteful and will have to be stopped in the interest of coming generations. The inevitable conclusion is that water power is by far our most valuable resource. On this humanity must build its hopes for the future. With its full development and a perfect system of wireless transmission of the energy to any distance, man will be able to solve all the problems of material existence. Distance, which is the chief impediment to human progress, will be completely annihilated in thought, word, and action. Humanity will be united, wars will be made impossible, and peace will reign supreme.”

The same article which contains this prophetic quotation from Tesla also notes that his

“World System” was conceptually based on three inventions of his:
1. The Tesla Transformer (Tesla coil)
2. The Magnifying Transmitter (transformer adapted to excite the earth)
3. The Wireless System (economic transmission of electrical energy without wires)

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4 Nikola Tesla, 1900, as quoted in “Great Scientist, Forgotten Genius, Nikola Tesla” by Chris Bird and Oliver Nichelson, New Age, #21, Feb. 1977, p. 42
Tesla states, “The first World System power plant can be put in operation in nine months. With this power plant it will be practicable to attain electrical activities up to 10 million horsepower (7.5 billion watts), and it is designed to serve for as many technical achievements as are possible without due expense.”

(Note that Tesla’s calculated power levels are conservatively estimated, compared to Rauscher’s calculations.)

The essay by Toby Grotz on the wireless transmission of power is a great introduction to this wireless power system of Tesla. It contains all of the details for a preliminary test of the system. His Figure 5 also illustrates the transmission of a high voltage pulse of electricity equally around the world where it rebounds at the opposite side and returns to its source, repeating the cycle many times. Grotz also worked with Dr. Corum on “Project TESLA,” which was a business venture designed to implement the wireless transmission of electricity.

Dr. Corum notes in his introductory article on the ELF (extremely low frequency) oscillator of Tesla’s that the tuned circuit of Tesla’s magnifying transmitter was the whole earth-ionosphere cavity. His second article presents probably the most complete article on Tesla’s magnifying transmitter that has ever been written. He explains in great detail the meaning of magnification as Tesla intended, with examples and equations. Even if not an engineer, I believe the reader will still appreciate the enthusiastic style with which the Corums describe Tesla’s developments regarding the TMT.

There are two diagrams produced at the turn of the century to help explain in simple terms Tesla’s wireless transmission of electrical power. The first is a mechanical “Analogy” that is

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Ibid., p.74
described in Corum’s ELF disclosure article. The second is the “Realization” which illustrates the usefulness of the power transmission concept.
Tesla wrote, "That electrical energy can be economically transmitted without wires to any terrestrial distance, I have unmistakably established in numerous observations, experiments and measurements, qualitative and quantitative. These have demonstrated that it is practicable
Harnessing the Wheelwork of Nature

to distribute power from a central plant in unlimited amounts, with a loss not exceeding a small fraction of one per cent in the transmission, even to the greatest distance, twelve thousand miles – to the opposite end of the globe."\(^6\)

Introduction to Tesla’s Science of Energy

As Tesla experimented with a 1.5 MW system in 1899 at Colorado Springs, he was amazed to find that pulses of electricity he sent out passed across the entire globe and returned with “undiminished strength.” He said, “It was a result so unbelievable that the revelation at first almost stunned me.”

This verified the tremendous efficiency of his peculiar method of pumping current into a spherical ball to charge it up before discharging it as a pulse of electrical energy, a “longitudinal” acoustic-type of compression wave, rather than an electromagnetic Hertzian-type of transverse wave.

It is also understood that Tesla planned to include stationary resonant wave creation as part of the wireless transmission of power. Examining the pair of 1900 patents #645,576 and #649,621 each using the same figure on the first page, we find in the first patent that Tesla has designed a quarter-wave antenna (50 miles of secondary coil wire for a 200 mile long wavelength). More importantly is the sphere on the top which is supposed to be a conductive surface on a balloon raised high enough to be radiating in “rarefied air.” As Tesla states, “That communication without wires to any point of the globe is practical with such apparatus would need no demonstration, but through a discovery which I made I obtained

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absolute certainty. Popularly explained it is exactly this: When we raise the voice and hear an echo in reply, we know that the sound of the voice must have reached a distant wall, or boundary, and must have been reflected from the same. Exactly as the sound, so an electrical wave is reflected, and the same evidence which is afforded by an echo is offered by an electrical phenomena known as a ‘stationary’ wave – that is, a wave with fixed nodal and ventral regions. Instead of sending sound vibrations toward a distant wall, I have sent electrical vibrations toward the remote boundaries of the earth, and instead of the wall, the earth has replied. In place of an echo, I have obtained a stationary electrical wave, a wave reflected from afar.\textsuperscript{8}

It is also worth calling attention to Corum’s disclosure article on the operation of an ELF oscillator, he proposes that Tesla’s x-ray patents were designed for the switching of high voltages in the charging and discharging of the dome of the Wardenclyffe tower (patent #1,119,732). Dr. Bass’ article elaborates on the details of longitudinal waves that would be created by such discharges. They have superior properties of transmission which normal radio and television waves today do not possess. Nikola Tesla was very familiar with their benefits.

\textsuperscript{8} Nikola Tesla, “The Problem of Increasing Human Energy,” \textit{Century}, June, 1900
Tesla states, “As to the transmission of power through space, that is a project which I considered absolutely certain of success long since. Years ago I was in the position to transmit wireless power to any distance without limit other than that imposed by the physical dimensions of the globe. In my system it makes no difference what the distance is. The efficiency of the transmission can be as high as 96 or 97 per cent, and there are practically no losses except such as are inevitable in the running of the machinery. When there is no
receiver there is no energy consumption anywhere. When the receiver is put on, it draws power. That is the exact opposite of the Hertz-wave system. In that case, if you have a plant of 1,000 horsepower (750 kW), it is radiating all the time whether the energy is received or not; but in my system no power is lost. When there are no receivers, the plant consumes only a few horsepower necessary to maintain the vibration; it runs idle, as the Edison plant when the lamps and motors are shut off.”

These incredible facts are explained by Dr. Corum and Spainol elsewhere, “…the distinction between Tesla’s system and ‘Hertzian’ waves is to be clearly understood. Tesla, and others of his day, used the term ‘Hertzian waves’ to describe what we call today, energy transfer by wireless transverse electromagnetic (TEM) radiation…no one wants to stand in front of a high power radar antenna. For these, E and H are in phase, the power flow is a ‘real’ quantity (as opposed to reactive – Ed. note), and the surface integral of E x H (Poynting vector – Ed. note) is nonzero. The case is not so simple in an unloaded power system, an RF transformer with a tuned secondary, or with a cavity resonator. In these situations, the fields are in phase quadrature, the circulating power is reactive and the average Poynting flux is zero – unless a load is applied. They deliver no power without a resistive load. These are clearly the power systems which Tesla created. The polyphase power distribution system was created by him in the 1880s and inaugurated at Niagara Falls in 1895. The RF transformer was invented and patented by him in the 1890s. Terrestrial resonances he experimentally discovered at the turn of the century. And, for the next 40 years he tried to bring through to commercial reality this global power system. Today, millions of us have working scale models of it in our kitchens, while the larger version sits idle.”

Receiving coil a great distance from the transmitter lighting a light bulb (white spot) in a test of Tesla’s wireless transmission of power in 1899.

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9 Nikola Tesla, “Minutes of the Annual Meeting of the AIEE,” May 18, 1917.  
In the same “Cavity Q” article, the authors also settle the most common criticism of the Tesla wireless power system regarding biological effects. Calculating the circulating reactive power, they find a density of a microVAR per cubic meter at 7.8 Hz to be quite small, while it is well-known that the frequency is very biologically compatible. The authors also look at the present 100 V/m field and again find that raising it by a factor of 4 to 10 will pose no ill effects. (Thunderstorms do it all of the time around the world.)
In 1925, an electrical engineer, John B Flowers, developed a proposal to test and implement Tesla’s Wireless Power System. He drafted the entire scheme for the Wardenclyffe project and presented it to H. L. Curtis, physicist, and J. H. Dillinger, head of the Radio Laboratory at the Bureau of Standards in Washington, DC. In a carefully worded 10-page document, complete with schematic drawings of the earth imbued with Tesla standing waves, Flowers unveiled a plan for operating cars and planes powered by wireless electricity (Sketch A). The plan was declined even though the mechanical test in Sketch B actually worked. Below is a report on the test results of the mechanical model of Tesla’s wireless system:

“Using the concepts in Sketch B, a mechanical oscillator arm was fastened to the tied opening of a rubber balloon 20 inches in diameter. The oscillator arm was operated with an
electrical motor at 1750 RPM by means of an eccentric on the motor shaft. The balloon hung free in the air. The rubber surface of the balloon represented the earth’s conducting surface and the air inside its insulating interior. The waves were propagated in the rubber surface at the rate of 51 feet per second, the frequency of transmission was 29 cycles per second and the wavelength was 21 inches. The mechanical oscillator was used in place of Tesla’s electrical oscillator as it presents an almost perfect analogy. Standing or stationary waves of the rubber surface replace the electromagnetic waves of Tesla’s system. By the test of this analog, the operation of Tesla’s system can be forecast. When the oscillator arm was set in motion by operating the motor, there were three standing waves having six loops on the ‘earth’s surface’ all having the same amplitude of vibration! When the finger was pushed against one or more loops, all the loops were reduced in amplitude in the same proportion showing the ability to
obtain all the power out at one or more points! The waves extended completely around the ‘world’ and returned to the sending station.”

Toby Grotz reports in his article that, in the 1980’s, about 1/3 of the generated electrical power in this country was lost in transmission. Today, a couple of decades later, we have shamefully doubled our dependence on foreign oil and also doubled our electrical transmission grid inefficiency. From 31 Quads generated, a full $\frac{2}{3}$ is totally wasted in “conversion losses.” (This is being repeated for emphasis.) No other energy production system of any kind in the world has so much wastefulness. Instead of trying to build 2 power plants per week (at 300 MW each) for the next 20 years (only to have a total of additional 6 trillion kWh available by 2020), as some U.S. government officials want to do, we simply need to eliminate the 7 trillion kWh of conversion losses in our present electricity generation modality. This book scientifically proves that Tesla’s wireless transmission of power will accomplish electrical distribution, better than centralized or even, dispersed generation.

Tesla discovered the evidence for charge clusters (as patented by Ken Shoulders and Hal Puthoff), the overunity effects of air arcs (as experimentally verified by Dr. Peter Graneau and George Hathaway), and the overunity effects of plasma glow discharge (as experimentally verified and patented by Dr. Paulo Correa).

Many believe it’s time for Westinghouse, General Electric, and the J.P. Morgan Foundation to generously support a non-profit vehicle, such as a “Nikola Tesla Institute,” to make amends for the billions that they reaped from Tesla’s inventions. Several are considering a class action lawsuit, on behalf of Tesla’s living descendants, to establish a trust fund. The reasons for legally attacking the profiteers of Tesla’s inventive genius to fulfill Tesla’s fondest dream of wireless transmission of power are the following. (This is a short list.)

1. General Electric, 1884: “Although Tesla had an antipathy toward the use of direct current motors, he worked to improve Edison’s dynamos. He was sure he could increase the output, lower the cost, and decrease the maintenance. Edison replied, ‘If you can do this, young man, it will be worth $50,000 to you.’ This would mean the realization of a laboratory for Tesla and the means for a life of scientific exploration. This was what he had visioned as the meaning of America’s golden promise. He set to work harder than ever, driving himself beyond his endurance, and as a result came up with the design of twenty-four different types of standard machines, short cores, and uniform patterns which were to replace the old ones. Edison was delighted with the results, but there was no $50,000 in Tesla’s pay envelope and after some time, Tesla approached him for the money. It is said that Edison replied, “Tesla, you don’t understand our American humor.” Tesla didn’t.”

   Tesla himself states this incident more succinctly, “For nearly a year my regular hours were from 10:30 AM until 5 o’clock the next morning without a day’s exception. Edison said to me: ‘I have had many hard-working assistants but you take the cake.’ During this period, I designed twenty-four different types of standard machines with short cores and of uniform pattern which were to replace the old ones. The Manager had promised me fifty thousand dollars on the completion of this task but it turned out to be a practical joke. This gave me a painful shock and I resigned my position.”

   The legal team will also detail all other legal nightmares caused by Edison, who continued to torture Tesla for years. Such examples include the court order to prevent Tesla from using GE light bulbs for

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11 J. B. Flowers, July 16, 1925, as quoted in Exotic Research Report, July, 1999, p. 48
the Pan American Exhibition of 1901 in Buffalo, NY and the egregious lies about a ‘debt-ridden company’ spread by Edison to depress Westinghouse stock, not to mention the electrocution of dogs at state fairs by Edison to show the dangers of AC electricity. It is ultimately possible that Edison can be implicated in the burning of Tesla’s NY laboratory in March, 1895, while he was out of the city. The motivation for the crime was overwhelming: Edison (General Electric) lost the Columbian Exposition light bulb contract to Westinghouse in 1892 to the tune of $400,000. General Electric also lost the generator contract for the three initial 5,000 horsepower generators at Niagara Falls in 1893 and was forced to secure a license for the use of Tesla patents. Tesla (Westinghouse) completed the powerhouse in 1895 and residents of Niagara Falls turned on the lights in April, 1895, proving the superiority of AC electricity. A year later and 20 miles away, Buffalo, NY would be the first city in the world to have electric street lamps. Meanwhile, GE lawyers could only repeatedly file petty lawsuits to wear down Westinghouse, so that eventually, it was called, “The War of the Currents.” The uneducated Edison led the groundless and unscrupulous battle by scaring the public with words like, “Just as certain as death, Westinghouse will kill a customer within six months after he puts in a system of any size. He has got a new thing and it will require a great deal of experimenting to get it working practically. It will never be free from danger.”

2. Westinghouse, 1888: Tesla was awarded patents on the AC system of motors and generators in May, 1888. “Within a few months, Westinghouse acquired the patented American rights and hired Tesla at a salary of $2,000 a month to work in Pittsburgh on the development of the polyphase system. Tesla’s system for the transmission and distribution of alternating current, including the induction motor, was covered by 40 historic patents. His motor was the missing link for today’s alternating current system of centralized electric generating stations capable of efficiently and economically distributing electricity over long distances. It is widely believed that Tesla received a million dollars for his patents and that Westinghouse was to pay Tesla $1 per horsepower for each AC motor produced. However, according to Westinghouse historical records, the contract specified that Tesla was to receive about $60,000 and earn $2.50 per horsepower for each motor produced. Four years after the contract was signed, it was rumored, the accrued royalties totaled approximately $12 million. Westinghouse was advised to get rid of the royalty contract when his form was in financial trouble and the fate of his company was at stake. So Westinghouse told Tesla he did not think he could honor the royalty clause…The 1897 annual report of Westinghouse shows that Tesla was paid $216,600 for outright purchase of the polyphase system patents.”

3. J. Pierpont Morgan, 1901: “It has been stated that Morgan simply gave Tesla $150,000 with no strings attached. Actually, there were plenty of strings attached. Morgan delayed his check for a few months. Finally it came with the stipulation that fifty-one percent of the patents relating to wireless telephony and telegraphy, not only those to

16 Ibid., p. 60 (Ed. note: the same facts are also found in O’Neill’s biography, Prodigal Genius.)
Harnessing the Wheelwork of Nature

be used in the present but the ones to be developed – all were to be in Morgan’s name. The $150,000 was well-secured...On March 1, 1901, Tesla sent to Morgan his contract, signing over the fifty-one percent interest in his patents and inventions and in any future ones relating to electric lighting and wireless telegraphy or telephony...Morgan’s $150,000 was woefully inadequate when Tesla considered all that must be done, but it was a start. He secured a tract of land on Long Island, about sixty miles from New York City, though an arrangement with James S. Warden. Tesla had pictured to Warden a glowing and convincing real estate boom in that site, employing several thousand people who would build their homes on the adjacent land. Warden cooperated to the extent of offering two hundred acres of land for the use of the scientist, twenty acres already cleared and with a well one hundred feet deep. By July 23, 1901, work had started on the project with the roads cleared and the right of way in order. Thus, within a little less than five months after the contract with Morgan was signed, work was started on Tesla’s giant project."

The rest of the horror story is history, as only the tower frame was erected in the next year. No more money was forthcoming for the project that Morgan initiated, even when the equipment cost alone cost about $200,000. Morgan believed that he would “have nothing to sell except antennas (and refused) to contribute to that charity.”

Tesla tried and tried for years until in 1917 the U.S. government blew up the abandoned Wardenclyffe tower because suspected German spies were seen “lurking” around it. With Edison as his willing ally, Morgan even publicly discredited Tesla’s name, so that all of the five school textbook publishers of the time removed any reference to him. Any wonder why even today, 100 years later, hardly anyone knows who Tesla is?

Upon reading the rest of this book, all of us who contributed to this book know that the engineers and physicists of the 21st century will come to appreciate the benefits of the tremendously efficient (about 95%) wireless transmission of power. In terms of today’s systems theory, Tesla understood that it is vital to “increase human energy” in order to maximize the quality of life worldwide. (See Puharich article for a detailed analysis of this Tesla theme.) In terms of economic theory, many countries will benefit from this service. At first, receiving stations will be needed. Just like television and radio, only an energy receiver is required, which may eventually be built into appliances, so no power cord will be necessary! Just think, monthly electric utility bills will be optional, like “cable TV.”

Tesla was an electrical genius who revolutionized our world in a way that DC power could never have accomplished, since the resistance of any transmission lines, (except perhaps, superconductive ones), is prohibitive for direct current. He deserved much better treatment from all three of the tycoons described above, than to spend the last 40 years of his life in abject poverty. However, he was too much of a gentleman to hold a grudge. Instead, regarding the magnifying transmitter, Tesla wrote in his autobiography, “I am unwilling to accord to some small-minded and jealous individuals the satisfaction of having thwarted my efforts. These men are to me nothing more than microbes of a nasty disease. My project was retarded by laws of nature. The world was not prepared for it. It was too far ahead of time. But the same laws will prevail in the end and make it a triumphal success.”

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17 Hunt and Draper, p. 136
20 Nikola Tesla, My Inventions, p. 91
This book is being published in time for the Wardenclyffe Tower Centennial, (1903-2003) which to many, signifies an extraordinary cause to remember and resurrect. Let us fulfill this prophesy of Tesla, making it a triumphal success, by supporting a philanthropic, international wireless power station to benefit the whole world. The scientists who contributed to this anthology are available to make such a global wonder a reality. The benefits, immediately alleviating electric power shortages everywhere, are too numerous to count. (For example, in Tesla’s homeland, the Electric Power Company of Serbia will raise their monthly rates by 50% on the day this book went to the publisher.) Are you willing to help make a world of difference?

(EDITORIAL COMMENTS ARE INSERTED IN MANY OF THE FOLLOWING CONTRIBUTED ARTICLES. THEY REPRESENT MY SCIENTIFIC VIEWPOINTS, WHICH MAY HELP OTHER RESEARCHERS. YOU CAN RECOGNIZE THESE ADDITIONS BY THE FAMILIAR ENDING: “– ED. NOTE.”)

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To all whom it may concern:

Believe known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Apparatus for the Utilization of Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors of electricity, the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be ether vibrations of extremely small wave-lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory here-tofore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or, even if not so, may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting-body connected to one of the terminals of a condenser while the other terminal of the same is made by independent means to receive or to carry away electricity a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or electrical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting-body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use, by preference, the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously. In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 677,071. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting-body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated. The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor supported at some height in the atmosphere or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of matter...
ter generally convey a positive charge to the
first condenser-terminal, which is connected to
the plate or conductor above mentioned, I
usually connect the second terminal of the
condenser to the ground, this being the most
convenient way of obtaining negative elec-
tricity, dispensing with the necessity of pro-
viding an artificial source. In order to util-
ize for any useful purpose the energy accu-
mulated in the condenser, I furthermore con-
nect to the terminals of the same circuit in-
cluding an instrument or apparatus which it
is desired to operate and another instrument
or device for alternately closing and opening
the circuit. This latter may be any form of
circuit-controller, with fixed or movable parts
or electrodes, which may be actuated either
by the stored energy or by independent means.
My discovery will be more fully understood
from the following description and annexed
drawings, to which reference is now made, and
in which—

Figure 1 is a diagram showing the general
arrangement of apparatus as usually em-
ployed. Fig. 2 is a similar diagram illustrat-
ing more in detail typical forms of the devices
or elements used in practice, and Figs. 3
and 4 are diagrammatical representations of modi-
\( T \)fied arrangements suitable for special pur-
poses.

As illustrative of the manner in which the
several parts or elements of the apparatus in
one of its simplest forms are to be arranged
and connected for useful operation, reference
is made to Fig. 1, in which C is the condenser,
P the insulated plate or conducting-body
which is exposed to the rays, and P another
plate or conductor which is grounded, all be-
ing joined in series, as shown. The terminals
TT of the condenser are also connected to a
circuit which includes a device R to be oper-
ated and a circuit-controlling device \( d \) of the
character above referred to.

The apparatus being arranged as shown, it
will be found that when the radiations of the
sun or of any other source capable of pro-
ducing the effects before described fall upon
the plate \( P \) an accumulation of electrical
energy in the condenser \( C \) will result. This
phenomenon, I believe, is best explained as
follows: The sun, as well as other sources of
radiant energy, throws off minute particles of
matter positively electrified, which, impinging
upon the plate \( P \), communicate continuously
an electrical charge to the same. The op-
posite terminal of the condenser being con-
nected to the ground, which may be consid-
ered as a vast reservoir of negative electricity,
a feeble current flows continuously into the
condenser, and inasmuch as these supposed
particles are of an inconceivably small radius
or curvature, and consequently charged to a
relatively very high potential, this charging of
the condenser may continue, as I have ac-
utually observed, almost indefinitely, even to
the point of rupturing the dielectric. If the
device \( d \) be of such character that it will op-
erate to close the circuit in which it is in-
cluded when the potential in the condenser
has reached a certain magnitude, the accumu-
lated charge will pass through the circuit,
which also includes the receiver R, and oper-
ate the latter.

In illustration of a particular form of appa-
tratus which may be used in carrying out
my discovery I now refer to Fig. 2. In this
figure, which in the general arrangement of
the elements is identical to Fig. 1, the device
\( d \) is shown as composed of two very thin con-
ducting-plates \( t, t' \), placed in close proximity
and very mobile, either by reason of extreme
flexibility or owing to the character of their
support. To improve their action, they should
be inclosed in a receptacle, from which the
air may be exhausted. The plates \( t, t' \) are
connected in series with a working circuit,
including a suitable receiver, which in this
case is shown as consisting of an electromag-
net \( M \), a movable armature \( a \), a retractile
spring \( b \), and a ratchet-wheel \( w \), provided
with a spring-pawl \( r \), which is pivoted to ar-
mature \( a \), as illustrated. When the radi-
ations of the sun or other radiant source fall
upon plate \( P \), a current flows into the con-
denser, as above explained, until the poten-
tial therein rises sufficiently to attract and
bring into contact the two plates \( t, t' \), and
thereby close the circuit connected to the two
condenser-terminals. This permits a flow of
current which energizes the magnet \( M \), caus-
ing it to draw down the armature \( a \) and im-
port a partial rotation to the ratchet-wheel
\( w \). As the current ceases the armature is
retracted by the spring \( b \), without, however,
moving the wheel \( w \). With the stoppage of
the current the plates \( t, t' \) cease to be attracted
and separate, thus restoring the circuit to its
original condition.

Fig. 3 shows a modified form of apparatus
used in connection with an artificial source
of radiant energy, which in this instance may
be an arc emitting copiously ultra-violet rays.
A suitable reflector may be provided for con-
centrating and directing the radiations. A
magnet \( R \) and circuit-controller \( d \) are ar-
anged as in the previous figures; but in the
present case the former instead of performing
itself the whole work only serves the purpose
of alternately opening and closing a local
circuit, containing a source of current \( B \) and
a receiving or translating device \( D \). The
controller \( d \), if desired, may consist of two
fixed electrodes separated by a minute air-
gap or weak dielectric film, which breaks
down more or less suddenly when a definite
difference of potential is reached at the ter-
minals of the condenser and returns to its
original state upon the passage of the dis-
charge.

Still another modification is shown in Fig.
4, in which the source \( S \) of radiant energy is
a special form of Roentgen tube devised by
me, having but one terminal \( k \), generally of
aluminium, in the form of half a sphere, with
plain polished surface on the front side,
from which the streams are thrown off. It
may be excited by attaching it to one of the
 terminals of any generator of sufficiently high
 electromotive force; but whatever apparatus
be used it is important that the tube be ex-
hausted to a high degree, as otherwise it might
prove entirely ineffective. The working or
discharge circuit connected to the terminals
\( T' \) of the condenser includes in this case
the primary \( p \) of a transformer and a circuit-
controller comprising a fixed terminal, or
brush \( f \) and a movable terminal \( f' \) in the shape
of a wheel, with conducting and insulating
segments, which may be rotated at an arbi-
trary speed by any suitable means. In in-
ductive relation to the primary wire or coil \( p \)
is a secondary \( s \), usually of a much greater
number of turns, to the ends of which is con-
ected a receiver \( R \). The terminals of the
condenser being connected, as indicated, one
to an insulated plate \( P \) and the other to a
grounded plate \( P' \), when the tube \( S \) is excited
rays or streams of matter are emitted from
the same, which convey a positive charge to
the plate \( P \) and condenser-terminal \( T \), while
terminal \( T' \) is continuously receiving nega-
tive electricity from the plate \( P' \). This, as
before explained, results in an accumulation
of electrical energy in the condenser, which
goes on as long as the circuit including the
primary \( p \) is interrupted. Whenever the cir-
cuit is closed owing to the rotation of the
terminal \( f' \), the stored energy is discharged
through the primary \( p \), this giving rise in the
secondary \( s \) to induced currents, which oper-
ate the receiver \( R \).

It is clear from what has been stated above
that if the terminal \( T' \) is connected to a plate
supplying positive instead of negative elec-
tricity the rays should convey negative elec-
tricity to plate \( P \). The source \( S \) may be any
form of Roentgen or Lenard tube; but it is
obvious from the theory of action that in
order to be very effective the electrical im-
ulses exciting it should be wholly or at least
preponderatingly of one sign. If ordinary
symmetrical alternating currents are em-
ployed, provision should be made for allow-
ing the rays to fall upon the plate \( P \) only
during those periods when they are produc-
tive of the desired result. Evidently if the
radiations of the source be stopped or inter-
cepted or their intensity varied in any man-
ner, as by periodically interrupting or rhythm-
ically varying the current exciting the source,
there will be corresponding changes in the
action upon the receiver \( R \), and thus signals
may be transmitted and many other useful
effects produced. Furthermore, it will be un-
derstood that any form of circuit-closer which
will respond to or be set in operation when a
predetermined amount of energy is stored in
the condenser may be used in lieu of the device
specifically described with reference to Fig. 2
and also that the special details of construc-
tion and arrangement of the several parts of
the apparatus may be very greatly varied with-
out departure from the invention.

Having described my invention, what I
claim is—

1. An apparatus for utilizing radiant en-
ergy, comprising in combination a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations, independent means
for charging the other armature, a circuit and
apparatus therein adapted to be operated or
controlled by the discharge of the condenser,
so set forth.

2. An apparatus for utilizing radiant en-
ergy, comprising in combination, a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations, independent means
for charging the other armature, a local cir-
cuit connected with the condenser-terminals,
a circuit-controller therein and means adapted
to be operated or controlled by the discharge
of the condenser when the local circuit is
closed, as set forth.

3. An apparatus for utilizing radiant en-
ergy, comprising in combination, a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations, independent means
for charging the other armature, a local cir-
cuit connected with the condenser-terminals,
a circuit-controller therein dependent for op-
eration on a given rise of potential in the con-
denser, and devices operated by the discharge
of the condenser when the local circuit is
closed, as set forth.

4. An apparatus for utilizing radiant en-
ergy, comprising in combination, a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations, and the other of
which is connected with the ground, a circuit
and apparatus therein adapted to be operated
by the discharge of the accumulated energy
in the condenser, as set forth.

5. An apparatus for utilizing radiant en-
ergy, comprising in combination, a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations and the other of
which is connected with the ground, a local

6. An apparatus for utilizing radiant en-
ergy, comprising in combination, a condenser,
one armature of which is subjected to the ac-
tion of rays or radiations and the other of
which is connected with the ground, a local

7. An apparatus for utilizing radiant en-
ergy, comprising a condenser, having one terminal connected to earth and the other to an elevated conducting-plate, which is adapted to receive the rays from a distant source of radiant energy, a local circuit connected with the condenser-terminals, a receiver therein, and a circuit-controller therefor which is adapted to be operated by a given rise of potential in the condenser, as set forth.

NIKOLA TESLA.

Witnesses:

M. LAWSON DYER,
RICHARD DONOVAN.
To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city, county, and State of New York, have invented certain new and useful Improvements in Methods of Utilizing Radiant Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It is well known that certain radiations—such as those of ultra-violet light, cathodic, Roentgen rays, or the like—possess the property of charging and discharging conductors.

It is likewise known that the discharge being particularly noticeable when the conductor upon which the rays impinge is negatively electrified. These radiations are generally considered to be other vibrations of extremely small wave lengths, and in explanation of the phenomena noted it has been assumed by some authorities that they ionize or render conducting the atmosphere through which they are propagated. My own experiments and observations, however, lead me to conclusions more in accord with the theory herebefore advanced by me that sources of such radiant energy throw off with great velocity minute particles of matter which are strongly electrified, and therefore capable of charging an electrical conductor, or even if not so may at any rate discharge an electrified conductor either by carrying off bodily its charge or otherwise.

My present application is based upon a discovery which I have made that when rays or radiations of the above kind are permitted to fall upon an insulated conducting body connected to one of the terminals of a condenser, while the other terminal of the same is made by independent means to receive or to carry away electricity, a current flows into the condenser so long as the insulated body is exposed to the rays, and under the conditions hereinafter specified an indefinite accumulation of electrical energy in the condenser takes place. This energy after a suitable time interval, during which the rays are allowed to act, may manifest itself in a powerful discharge, which may be utilized for the operation or control of mechanical or electrical devices or rendered useful in many other ways.

In applying my discovery I provide a condenser, preferably of considerable electrostatic capacity, and connect one of its terminals to an insulated metal plate or other conducting body exposed to the rays or streams of radiant matter. It is very important, particularly in view of the fact that electrical energy is generally supplied at a very slow rate to the condenser, to construct the same with the greatest care. I use by preference the best quality of mica as dielectric, taking every possible precaution in insulating the armatures, so that the instrument may withstand great electrical pressures without leaking and may leave no perceptible electrification when discharging instantaneously.

In practice I have found that the best results are obtained with condensers treated in the manner described in a patent granted to me February 23, 1897, No. 577,671. Obviously the above precautions should be the more rigorously observed the slower the rate of charging and the smaller the time interval during which the energy is allowed to accumulate in the condenser. The insulated plate or conducting body should present as large a surface as practicable to the rays or streams of matter, I having ascertained that the amount of energy conveyed to it per unit of time is under otherwise identical conditions proportionate to the area exposed, or nearly so. Furthermore, the surface should be clean and preferably highly polished or amalgamated.

The second terminal or armature of the condenser may be connected to one of the poles of a battery or other source of electricity or to any conducting body or object whatever of such properties or so conditioned that by its means electricity of the required sign will be supplied to the terminal. A simple way of supplying positive or negative electricity to the terminal is to connect the same either to an insulated conductor, supported at some height in the atmosphere, or to a grounded conductor, the former, as is well known, furnishing positive and the latter negative electricity. As the rays or supposed streams of matter generally convey a positive charge to the first condenser-terminal, which is connect-
ed to the plate or conductor above mentioned, I usually connect the second terminal of the condenser to the ground, this being the most convenient way of obtaining negative electricity, dispensing with the necessity of providing an artificial source. In order to utilize for any useful purpose the energy accumulated in the condenser, I furthermore connect to the terminals of the same a circuit including an instrument or apparatus which it is desired to operate and another instrument or device for alternately closing and opening the circuit. This latter may be any form of circuit-controller, with fixed or movable parts or electrodes, which may be actuated either by the stored energy or by independent means.

The rays or radiations which are to be utilized for the operation of the apparatus above described in general terms may be derived from a natural source, as the sun, or may be artificially produced by such means, for example, as an arc-lamp, a Roentgen tube, and the like, and they may be employed for a great variety of useful purposes.

This discovery will be more fully understood from the following detailed description and annexed drawings, to which reference is now made, and in which—

Figure 1 is a diagram showing typical forms of the devices or elements as arranged and connected in applying the method for the operation of a mechanical contrivance or instrument solely by the energy stored; and Fig. 2 is a diagrammatical representation of a modified arrangement suitable for special purposes, with a circuit-controller actuated by independent means.

Referring to Fig. 1, C is the condenser, P the insulated plate or conducting body, which is exposed to the rays, and P' another plate or conductor, all being joined in series, as shown. The terminals T T' of the condenser are also connected to a circuit including a receiver R, which is to be operated, and a circuit-controlling device d, which in this case is composed of two very thin conducting-plates t t', placed in close proximity and very mobile, either by reason of extreme flexibility or owing to the character of their support. To improve their action, they should be inclosed in a receptacle from which the air may be exhausted. The receiver R is shown as consisting of an electromagnet M, a movable armature a, a retractile spring b, and a ratchet-wheel w, provided with a spring-pawl r, which is pivoted to armature a, as illustrated. The apparatus being arranged as shown, it will be found that when the radiations of the sun or of any other source capable of producing the effects before described fall upon the plate P an accumulation of electrical energy in the condenser C will result. This phenomenon, I believe, is best explained as follows: The sun as well as other sources of radiant energy throw off matter positively electrified, which, impinging upon the plate P, communicate an electrical charge to the same. The opposite terminal of the condenser being connected to the ground, which may be considered as a vast reservoir of negative electricity, a feeble current flows continuously into the condenser, and inasmuch as these supposed particles are of an inconceivably small radius or curvature, and consequently charged to a relatively very high potential, the charging of the condenser may continue, as I have found in practice, almost indefinitely, even to the point of rupturing the dielectric. Obviously whatever circuit-controller be employed it should operate to close the circuit in which it is included when the potential in the condenser has reached the desired magnitude. Thus in Fig. 2 when the electrical pressure at the terminals T T' rises to a certain predetermined value the plates t t', attracting each other, close the circuit connected to the terminals. This permits a flow of current which energizes the magnet M, causing it to work down the armature a and impart a partial rotation to the ratchet-wheel w. As the current ceases the armature is retracted by the spring b without, however, moving the wheel w. With the stoppage of the current the plates t t' cease to be attracted and separate, thus restoring the circuit to its original condition.

Many useful applications of this method of utilizing the radiations emanating from the sun or other source and many ways of carrying out the same will at once suggest themselves from the above description. By way of illustration a modified arrangement is shown in Fig. 2, in which the source S of radiant energy is a special form of Roentgen tube devised by me having but one terminal k, generally of aluminum, in the form of half a sphere with a plain polished surface on the front side, from which the streams are thrown off. It may be excited by attaching it to one of the terminals of any generator of sufficiently high electromotive force; but whatever apparatus be used it is important that the tube be exhausted to a high degree, as otherwise it might prove entirely ineffective. The working or discharge circuit connected to the terminals T T' of the condenser includes in this case the primary p of a transformer and a circuit-controller comprising a fixed terminal or brush t and a movable terminal t' in the shape of a wheel with conducting and insulating segments which may be rotated at an arbitrary speed by any suitable means. In inductive relation to the primary wire or coil p is a secondary s, usually of a much greater number of turns, to the ends of which is connected a receiver R. The terminals of the condenser being connected as indicated, one to an insulated plate P and the other to a grounded plate P' when the tube S is excited rays or streams of matter are emitted from the same, which convey a positive charge to the plate P and condenser-terminal T, while terminal T' is continuously receiving negative electricity from the plate.
P'. This, as before explained, results in an accumulation of electrical energy in the condenser, which goes on as long as the circuit including the primary p is interrupted. Whenever the circuit is closed, owing to the rotation of the terminal t', the stored energy is discharged through the primary p, this giving rise in the secondary s to induced currents which operate the receiver R.

It is clear from what has been stated above that if the terminal T' is connected to a plate supplying positive instead of negative electricity the rays should convey negative electricity to plate P. The source S may be any form of Roentgen or Lenard tube; but it is obvious from the theory of action that in order to be very effective the electrical impulses exciting it should be wholly or at least preponderantly of one sign. If ordinary symmetrical alternating currents are employed, provision should be made for allowing the rays to fall upon the plate P only during those periods when they are productive of the desired result. Evidently if the radiations of the source be stopped or intercepted or their intensity varied in any manner, as by periodically interrupting or rhythmically varying the current exciting the source, there will be corresponding changes in the action upon the receiver R, and thus signals may be transmitted and many other useful effects produced. Furthermore, it will be understood that any form of circuit-closer which will respond to or be set in operation when a predetermined amount of energy is stored in the condenser may be used in lieu of the device specifically described with reference to Fig. 1, and also that the special details of construction and arrangement of the several parts of the apparatus may be very greatly varied without departure from the invention.

Having described my invention, what I claim is—

1. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other armature by independent means, and discharging the condenser through a suitable receiver, as set forth.

2. The method of utilizing radiant energy, which consists in simultaneously charging a condenser by means of rays or radiations and an independent source of electrical energy, and discharging the condenser through a suitable receiver, as set forth.

3. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations, and the other by independent means, controlling the action or effect of said rays or radiations and discharging the condenser through a suitable receiver, as set forth.

4. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations and the other by independent means, varying the intensity of the said rays or radiations periodically and discharging the condenser through a suitable receiver, as set forth.

5. The method of utilizing radiant energy, which consists in directing upon an elevated conductor, connected to one of the armatures of a condenser, rays or radiations capable of positively electrifying the same, carrying off electricity from the other armature by connecting the same with the ground, and discharging the accumulated energy through a suitable receiver, as set forth.

6. The method of utilizing radiant energy, which consists in charging one of the armatures of a condenser by rays or radiations and the other by independent means, and effecting by the automatic discharge of the accumulated energy the operation or control of a suitable receiver, as set forth.

Witnesses:

M. LAWSON DYER,
RICHARD DONOVAN.

NIKOLA TESLA.
N. TESLA.

METHOD OF UTILIZING RADIANT ENERGY.

(Application filed Mar. 21, 1901.)

Fig. 1

Fig. 2

Witnesses:

Raphael Belto
M. Davidson Tyor

Nikola Tesla, Inventor

by Rev. Page T. Cooper

Albys
“With reference to the facts which have been pointed out above it will be seen that the altitudes required for the transmission of considerable amounts of electrical energy in accordance with this method are such as are easily accessible and at which terminals can be safely maintained, as by the aid of captive balloons supplied continuously with gas from reservoirs and held in position securely by steel wires or by any other means, devices, or expedients, such as may be contrived and perfected by ingenious and skilled engineers. From my experiments and observations I conclude that with electromotive impulses not greatly exceeding fifteen or twenty million volts the energy of many thousands of horse-power may be transmitted over vast distances, measured by many hundreds and even thousands of miles, with terminals not more than thirty to thirty-five thousand feet above the level of the sea, and even this comparatively-small elevation will be required chiefly for reasons of economy, and, if desired, it may be considerably reduced, since by such means as have been described practically any potential that is desired may be obtained, the currents through the air strata may be rendered very small, whereby the loss in the transmission may be reduced.”

While power would be transmitted through the earth, Tesla completed the circuit by elevating the terminals into the atmosphere by using balloons. In the upper atmosphere, Tesla believed the thinner air would allow currents to be conducted.
It is a well-known laboratory fact that rarefied air is a conductor of electricity, though one of much resistance. The Crookes tubes of X ray fame depend on this principle. With one sweep Tesla takes this principle from the laboratories where, only, men have put it to use, and goes up to the clouds with it. He produces a wonderful voltage that will jump an enormous distance in every-day air, and proposes to take it in balloons up to where the air is a sort of natural Crookes tube. In such an altitude it will jump long distances to another terminal, he says, the layer of heavy air below being a non-conductor and resisting it like the rubber wrapping of a wire, for ordinary air is not a good conductor.

Tesla is the pioneer of high voltages. Some time ago he invented an "oscillator" a purely Tesla contrivance, for this purpose. He has been making them bigger and bigger and his last one gets up to 2,500,000 volts. The accompanying illustration shows his latest oscillator in action.

The diagrams illustrate the theory of the apparatus. In the transmitting apparatus A is an insulated high tension coil about a magnetic core. C is a second coil of larger wire. The terminals of both coils are shown. G is the generator or source of current. D is a balloon acting as a terminal itself or a terminal supported by a balloon to which the current passes. The current is supposed to pass through the rarefied upper air from D to D1, a receiving balloon at a great distance. The primary and secondary coils of the receiving apparatus are the reverse of the transmitter. L and M indicate lamps and motors to be energized by the transmitted current.

In the long descriptive text accompanying the inventor’s application for a patent it is said that the invention comprises a novel method for the transmission of electrical energy without the employment of metallic line conductors, but the results arrived at are of such character and magnitude as compared with any heretofore secured as to render indispensable the employment of means and the utilization of effect essentially different in their characteristics and actions from those before used or investigated.
To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Systems of Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

It has been well known heretofore that by rarefying the air inclosed in a vessel its insulating properties are impaired to such an extent that it becomes what may be considered as a true conductor, although one of admittedly very high resistance. The practical information in this regard has been derived from observations necessarily limited in their scope by the character of the apparatus or means heretofore known and the quality of the electrical effects producible thereby. Thus it has been shown by William Crookes in his classical researches, which have so far served as the chief source of knowledge of this subject, that all gases behave as excellent insulators until rarefied to a point corresponding to a barometric pressure of about seventy-five millimeters, and even at this very low pressure the discharge of a high-tension induction-coil passes through only a part of the attenuated gas in the form of a luminous thread or arc, a still further and considerable diminution of the pressure being required to render the entire mass of the gas inclosed in a vessel conducting. While this is true in every particular so long as electromotive or current impulses such as are obtainable with ordinary forms of apparatus are employed, I have found that neither the general behavior of the gases nor the known relations between electrical conductivity and pressure are in conformity with these observations when impulses are used such as are producible by methods and apparatus devised by me and which have peculiar and hitherto unobserved properties and are of effective electromotive forces, measuring many hundred thousands or millions of volts. Through the continuous perfection of these methods and apparatus and the investigation of the actions of these current impulses I have been led to the discovery of certain highly-important and useful facts which have hitherto been unknown. Among these and bearing directly upon the subject of my present application are the following: First, that atmospheric or other gases, even under normal pressure, when they are known to behave as perfect insulators, are in a large measure deprived of their dielectric properties by being subjected to the influence of electromotive impulses of the character and magnitude I have referred to and assume conducting and other qualities which have been so far observed only in gases greatly attenuated or heated to a high temperature, and, second, that the conductivity imparted to the air or gases increases very rapidly both with the augmentation of the applied electrical pressure and with the degree of rarefaction, the law in this latter respect being, however, quite different from that heretofore established. In illustration of these facts a few observations, which I have made with apparatus devised for the purposes here contemplated, may be cited. For example, a conductor or terminal, to which impulses such as those here considered are supplied, but which is otherwise insulated in space and is remote from any conducting-bodies, is surrounded by a luminous flame-like brush or discharge often covering many hundreds or even as much as several thousands of square feet of surface, this striking phenomenon clearly attesting the high degree of conductivity which the atmosphere attains under the influence of the immense electrical stresses to which it is subjected. This influence is, however, not confined to that portion of the atmosphere which is discernible by the eye as luminous and which, as has been the case in some instances actually observed, may fill the space within a spherical or cylindrical envelope of sixty feet or more, but reaches out to far remote regions, the insulating qualities of the air being, as I have ascertained, still sensibly impaired at a distance many hundred times that through which the luminous discharge projects from the terminal and in all probability much farther. The distance extends with the increase of the electromotive force of the impulses, with the diminution of the density of the atmosphere, with the elevation of the active terminal above the ground, and also, apparently, in a slight measure, with the degree of moisture contained in
the air. I have likewise observed that this region of decidedly-noticeable influence continuously enlarges as time goes on, and the discharge is allowed to pass not unlike a con
5 ignition which slowly spreads, this being possibly due to the gradual electrification or ionization of the air or to the formation of less insulating gaseous compounds. It is, furthermore, a fact that such discharges of extreme tensions, approximating those of lightning, manifest a marked tendency to pass upward away from the ground, which may be due to electrostatic repulsion, or possibly to slight heating and consequent rising of the electrified or ionized air. These latter observations make it appear probable that a discharge of this character allowed to escape into the atmosphere from a terminal maintained at a great height will gradually lead through and establish a good conducting-path to more elevated and better conducting air strata, a process which possibly takes place in silent lightning discharges frequently witnessed on hot and very dry days. It will be apparent to what an extent the conductivity imparted to the air is enhanced by the increase of the electromotive force of the impulses when it is stated that in some instances the area covered by the flame discharge mentioned was enlarged more than sixfold by an augmentation of the electrical pressure, amounting scarcely to more than fifty per cent. As to the influence of rarefaction upon the electric conductivity imparted to the gases it is noteworthy that, whereas the atmospheric or other gases begin ordinarily to manifest this quality at something like seventy-five millimeters barometric pressure with the impulses of excessive electromotive force to which I have referred, the conductivity, as already pointed out, begins even at normal pressure and continuously increases with the degree of tenacity of the gas, so that, say, one hundred and thirty millimeters pressure, 40 when the gases are known to be still nearly perfect insulators for ordinary electromotive forces, they behave toward electromotive impulses of several millions of volts like excellent conductors, as though they were rarefied to a much higher degree. By the discovery of these facts and the perfection of means for producing in a safe, economical, and thoroughly-practicable manner current impulses of the character described it becomes possible to transmit through easily-accessible and only moderately-rarefied strata of the atmosphere electrical energy not merely in insignificant quantities, such as are suitable for the operation of delicate instruments and like purposes, but also in quantities suitable for industrial uses on a large scale up to practically any amount and, according to all the experimental evidence I have obtained, to any terrestrial distance. To conduce to a better understanding of this method of transmission of energy and to distinguish it clearly, both in its theoretical aspect and in its practical bearing, from other known modes of transmission, it is useful to state that all previous efforts made by myself and others for transmitting electrical energy to a distance without the use of metallic conductors, chiefly with the object of acting sensitive receivers, have been based, in so far as the atmosphere is concerned, upon those qualities which it possesses by virtue of its being an excellent insulator, and all these attempts would have been obviously recognized as ineffective if not entirely futile in the presence of a conducting atmosphere or medium. The utilization of any conducting properties of the air for purposes of transmission of energy has been hitherto out of the question in the absence of apparatus suitable for maintaining the many and difficult requirements, although it has long been known or surmised that atmospheric strata at great altitudes—say fifteen or more miles above sea-level—are, or should be, in a measure, conducting; but assuming even that the indispensable means should have been produced then still a difficulty, which in the present state of the mechanical arts must be considered as insuperable, would remain—namely, that of maintaining terminals at elevations of fifteen miles or more above the level of the sea. Through my discoveries before mentioned and the production of adequate means the necessity of maintaining terminals at such inaccessible altitudes is obviated and a practical method and system of transmission of energy through the natural media is afforded essentially different from all those available up to the present time and possessing, moreover, this important practical advantage, that whereas in all such methods or systems heretofore used or proposed but a minute fraction of the total energy expended by the generator or transmitter was recoverable in a distant receiving apparatus by my method and appliances it is possible to utilize by far the greater portion of the energy of the source and in any locality however remote from the same. Expressed briefly, my present invention, based upon these discoveries, consists then in producing at one point an electrical pressure of such character and magnitude as to cause thereby a current to traverse elevated strata of the air between the point of generation and a distant point at which the energy is to be received and utilized. In the accompanying drawing a general arrangement of apparatus is diagrammatically illustrated such as I contemplate employing in the carrying out of my invention on an industrial scale—as, for instance, for lighting distant cities or districts from places where cheap power is obtainable. Referring to the drawing, A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be found necessary. C is a second coil, formed of a conductor of much larger section and smaller
length, wound around and in proximity to the coil A. In the transmitting apparatus the coil A constitutes the high-tension secondary and the coil C the primary of much lower tension of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission, as before described. The other terminal of the secondary A is connected to earth and, if desired, also to the primary in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving-station a transformer of similar construction is employed; but in this case the coil A', of relatively-thin wire, constitutes the primary and the coil C', of thick wire or cable, the secondary of the transformer. In the circuit of the latter are included lamps J, motors M, or other devices for utilizing the current. The elevated terminal D' is connected with the center of the coil A', and the other terminal of said coil is connected to earth and preferably, also, to the coil C' for the reasons above stated.

It will be observed that in coils of the character described the potential gradually increases with the number of turns toward the center, and the difference of potential between the adjacent turns being comparatively small a very high potential, impracticable with ordinary coils, may be successfully obtained. It will be, furthermore, noted that no matter to what extent the coils may be modified in design and construction, owing to their general arrangement and manner of connection, as illustrated, those portions of the wire or apparatus which are highly charged will be out of reach, while those parts of the same which are liable to be approached, touched, or handled will be at or nearly the same potential as the adjacent portions of the ground, this insuring, both in the transmitting and receiving apparatuses and regardless of the magnitude of the electrical pressure used, perfect personal safety, which is best evidenced by the fact that although such extreme pressures of many millions of volts have been for a number of years continuously experimented with no injury has been sustained either by myself or any of my assistants.

The length of the thiu-wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used.

By way of illustration if the rate at which the current traverses the circuit, including the coil, be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary waves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length. For such a low frequency, to which I shall resort only when it is indispensable to operate motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or proportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D, and it should be understood that whatever length be given to the wires this condition should be complied with in order to attain the best results.

As the main requirement in carrying out my invention is to produce currents of an excessively-high potential, this object will be facilitated by using a primary current of very considerable frequency, since the electromotive force obtainable with a given length of conductor is proportionate to the frequency; but the frequency of the current is in a large measure arbitrary, for if the potential be sufficiently high and if the terminals of the coils be maintained at the proper altitudes the action described will take place, and a current will be transmitted through the elevated air strata, which will encounter little and possibly even less resistance than if conveyed through a copper wire of a practicable size. Accordingly the construction of the apparatus may be in many details greatly varied; but in order to enable any person skilled in the mechanical and electrical arts to utilize to advantage in the practical applications of my system the experience I have so far gained the following particulars of a model plant which has been long in use and which was constructed for the purpose of obtaining further data to be used in the carrying out of my invention on a large scale are given. The transmitting apparatus was in this case one of my electrical oscillators, which are transformers of a special type, now well known and characterized by the passage of oscillatory discharges of a condenser through the primary. The source G, forming one of the elements of the transmitter, was a condenser of a capacity of about four one-hundredths of a microfarad and was charged from a generator of alternating currents of fifty thousand volts pressure and discharged by means of a mechanically-operated break five thousand times per second through the primary C. The latter consisted of a single turn of stout stranded cable of inappreciable resistance and of an inductance of about eight thousand centimeters, the diameter of the loop being very nearly two hundred and forty-four centimeters. The total inductance of the primary circuit was approximately ten thousand centimeters, so that the primary circuit vibrated generally according to adjustment,
from two hundred and thirty thousand to two hundred and fifty thousand times per second. The high-tension coil A in the form of a flat spiral was composed of fifty turns of highly-insulated cable No. 8 wound in one single layer, the turns beginning close to the primary loop and ending near its center. The outer end of the secondary or high-tension coil A was connected to the ground, as illustrated, while the free end was led to a terminal placed in the rarefied air stratum through which the energy was to be transmitted, which was contained in an insulating-tube of length of fifty feet or more, within which a barometric pressure varying from about one hundred and twenty to one hundred and fifty millimeters was maintained by means of a mechanical suction-pump. The receiving-transformer was similarly proportioned, the ratio of conversion being the reciprocal of that of the transmitter, and the primary high-tension coil A’ was connected, as illustrated, with the end near the low-tension coil C’ to the ground and with the end near a wire or plate likewise placed in the rarefied air stratum and at the distance named from the transmitting-terminal. The primary and secondary circuits in the transmitting apparatus being carefully synchronized, an electromotive force from two to four million volts and more was obtainable at the terminals of the secondary coil A, the discharge passing freely through the attenuated air stratum maintained at the above barometric pressures, and it was easy under these conditions to transmit with fair economy considerable amounts of energy, such as are of industrial moment, to the receiving apparatus for supplying from the secondary coil C’ lamps L or kindred devices. The results were particularly satisfactory when the primary coil or system A, with its secondary C’, was carefully adjusted, so as to vibrate in synchronism with the transmitting coil or system A C. I have, however, found no difficulty in producing with apparatus of substantially the same design and construction electromotive forces exceeding three or four times those before mentioned and have ascertained that by their means current impulses can be transmitted through much denser air strata. By the use of these I have also found it practicable to transmit notable amounts of energy through air strata not in direct contact with the transmitting and receiving terminals, but remote from them, the action of the impulses, in rendering conducting air of a density at which it normally behaves as an insulator, extending, as they’re remarked, to a considerable distance. The high electromotive force obtained at the terminals of coil or conductor A was, as will be seen, in the preceding instance, not so much due to a large ratio of transformation as to the joint effect of the capacities and inductances in the synchronized circuits, which effect is enhanced by a high frequency, and it will be obviously understood that if the latter be reduced a greater ratio of transformation should be resorted to, especially in cases in which it may be deemed of advantage to suppress as much as possible, and particularly in the transmitting-coil A, the rise of pressure due to the above effect and to obtain the necessary electromotive force solely by a large transformation ratio. While electromotive forces such as are produced by the apparatus just described may be sufficient for many purposes to which my system will or may be applied, I wish to state that I contemplate using in an industrial undertaking of this kind forces greatly in excess of these, and with my present knowledge and experience in this novel field I would estimate them to range from twenty to fifty million volts and possibly more. By the use of these much greater forces larger amounts of energy may be conveyed through the atmosphere to remote places or regions, and the distance of transmission may be thus extended practically without limit.

As to the elevation of the terminals D D’ it is obvious that it will be determined by a number of things, as by the amount and quality of the work to be performed, by the local density and other conditions of the atmosphere, by the character of the surrounding country, and such considerations as may present themselves in individual instances. Thus if there be high mountains in the vicinity the terminals should be at a greater height, and generally they should always be, if practicable, at altitudes much greater than those of the highest objects near them in order to avoid as much as possible the loss by leakage. In some cases when small amounts of energy are required the high elevation of the terminals, and more particularly of the receiving - terminal D’, may not be necessary, since, especially when the frequency of the currents is very high, a sufficient amount of energy may be collected at that terminal by electrostatic induction from the upper air strata, which are rendered conducting by the active terminal of the transmitter or through which the currents from the same are conveyed.

With reference to the facts which have been pointed out above it will be seen that the altitudes required for the transmission of considerable amounts of electrical energy in accordance with this method are such as are easily accessible and at which terminals can be safely maintained, as by the aid of captive balloons supplied continuously with gas from reservoirs and held in position securely by steel wires or by any other means, devices, or expedients, such as may be contrived and perfected by ingenious and skilled engineers. From my experiments and observations I conclude that with electromotive impulses not greatly exceeding fifteen or twenty million volts the energy of many thousands of horse-power may be transmitted over vast distances, measured by many hundreds and
even thousands of miles, with terminals not more than thirty to thirty-five thousand feet above the level of the sea, and even this comparatively small elevation will be required chiefly for reasons of economy, and, if desired, it may be considerably reduced, since by such means as have been described practically any potential that is desired may be obtained, the currents through the air strata may be rendered very small, whereby the loss in the transmission may be reduced.

It will be understood that the transmitting as well as the receiving coils, transformers, or other apparatus may be in some cases movable—as, for example, when they are carried by vessels floating in the air or by ships at sea. In such a case, or generally, the connection of one of the terminals of the high-tension coil or coils to the ground may not be permanent, but may be intermittently or indifferently established, and any such or similar modifications I shall consider as within the scope of this invention.

While the description here given contemplates chiefly a method and system of energy transmission to a distance through the natural media for industrial purposes, the principles which I have herein disclosed and the apparatus which I have shown will obviously have many other valuable uses—as, for instance, when it is desired to transmit intelligible messages to great distances, or to illuminate upper strata of the air, or to produce, designedly, any useful changes in the condition of the atmosphere, or to manufacture from the gases of the same products, as nitric acid, fertilizing compounds, or the like, by the action of such current impulses, for all of which and for many other valuable purposes they are eminently suitable, and I do not wish to limit myself in this respect. Obviously, also, certain features of my invention here disclosed will be useful as disconnected from the method itself—as, for example, in other systems of energy transmission, for whatever purpose they may be intended, the transmitting and receiving transformers arranged and connected as illustrated, the feature of a transmitting and receiving coil or conductor, both connected to the ground and to an elevated terminal and adjusted so as to vibrate in synchronism, the proportioning of such conductors or coils, as above specified, the feature of a receiving-transformer with its primary connected to earth and to an elevated terminal and having the operative devices in its secondary, and other features or particulars, such as have been described in this specification or will readily suggest themselves by a perusal of the same.

I do not claim in this application a transformer for developing or converting currents of high potential in the form herewith shown and described and with the two coils connected together, as and for the purpose set forth, having made these improvements the subject of a patent granted to me November 2, 1897, No. 593,138, nor do I claim herein the apparatus employed in carrying out the method of this application when such apparatus is specially constructed and arranged for securing the particular object sought in the present invention, as these last-named features are made the subject of an application filed as a division of this application on February 19, 1900, Serial No. 5,780.

What I now claim is—

1. The method hereinafter described of transmitting electrical energy through the natural media, which consists in producing at a generating-station a very high electrical pressure, causing thereby a propagation or flow of electrical energy, by conduction, through the earth and the air strata, and collecting or receiving at a distant point the electrical energy so propagated or caused to flow.

2. The method hereinafter described of transmitting electrical energy, which consists in producing at a generating-station a very high electrical pressure, converting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first.

3. The method hereinafter described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

4. The method hereinafter described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render the air strata at or near the elevated terminal conducting, causing thereby a propagation or flow of electrical energy, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station the electrical energy so propagated or caused to flow.

5. The method hereinafter described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby current impulses to pass, by conduction, through the air strata, and collecting or receiving at a point distant from the generating-station, the energy of the current impulses by means of a circuit synchronized with the impulses.

0. The method hereinafter described of
transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a sufficiently-high electromotive force to render the air strata at or near the elevated terminal conducting, causing thereby current impulses to pass through the air strata, and collecting or receiving at a point distant from the generating-station the energy of the current impulses by means of a circuit synchronized with the impulses.

7. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, electrical impulses of a wave length so related to the length of the generating circuit or conductor as to produce the maximum potential at the elevated terminal, and of sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation of electrical impulses through the air strata, and collecting or receiving at a point distant from the generating-station the energy of such impulses by means of a receiving-circuit having a length of conductor similarly related to the wave length of the impulses.

8. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in producing between the earth and a generator-terminal elevated above the same, at a generating-station, a sufficiently-high electromotive force to render elevated air strata conducting, causing thereby a propagation or flow of electrical energy through the air strata, by conduction, collecting or receiving the energy so transmitted by means of a receiving-circuit at a point distant from the generating-station, using the receiving-circuit to energize a secondary circuit, and operating translating devices by means of the energy so obtained in the secondary circuit.

9. The method hereinbefore described of transmitting electrical energy through the natural media, which consists in generating current impulses of relatively-low electromotive force at a generating-station, utilizing such impulses to energize the primary of a transformer, generating by means of such primary circuit impulses in a secondary surrounding by the primary and connected to the earth and to an elevated terminal, of sufficiently-high electromotive force to render elevated air strata conducting, causing thereby impulses to be propagated through the air strata, collecting or receiving the energy of such impulses, at a point distant from the generating-station, by means of a receiving-circuit connected to the earth and to an elevated terminal, and utilizing the energy so received to energize a secondary circuit of low potential surrounding the receiving-circuit.

NIKOLA TESLA.

Witnesses:
M. LAWSON DYER,
G. W. MARTLING.
N. TESLA.

METHOD OF OPERATING ARC LAMPS.

No. 447,920. Patented Mar. 10, 1891.
METHOD OF OPERATING ARC LAMPS.

SPECIFICATION forming part of Letters Patent No. 447,929, dated March 10, 1891.
Application filed October 1, 1890. Serial No. 366,794. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Operating Arc Lamps, of which the following is a specification.

This invention consists in an improved method of operating electric-arc lamps which are supplied with alternating or pulsating currents.

It has now become a common practice to run arc lamps by alternating or pulsating as distinguished from continuous currents; but an objection to such systems exists in the fact that the arcs emit a pronounced sound, varying with the rate of the alternations or pulsations of current, but under any circumstances constituting an objectionable and disagreeable feature, for which heretofore no effective remedy has been found or proposed. This noise is probably due to the rapid alternation, heating and cooling and consequent expansion and contraction of the gaseous matter forming the arc which corresponds with the periods or impulses of the current; for I have succeeded in abating it and producing quiet and smoothly-acting lamps by increasing, per unit of time, the number of alternations or pulsations of the current producing the arc to such an extent that the rate of the vibrations or changes in the arc producing the noise approximately equals or exceeds that which is generally regarded as the limit of audition. For example, I may use a generator which produces ten thousand or more alternations of current per second. In such a case the periodical heating and cooling of the arc would occur with such rapidity as to produce little or no perceptible effect upon the ear.

There are a number of ways in which the current may be varied at a rate exceeding the limit of audition, but probably the most practicable known to me at present is by the use of an alternating-current generator with a large number of poles, and specially constructed for the purpose. Such a generator, for the purpose of the illustration of this case, I have shown in the accompanying drawings.

Figure 1 is a view of the generator in side elevation. Fig. 2 is a vertical cross-section of the same with a diagram of the circuit-connections. Fig. 3 is an enlarged view, in side elevation, of a part of the machine. Fig. 4 is an enlarged sectional detail of the armature and field. Fig. 5 is a detail section of the field-magnets exhibiting the plan of winding.

A is an annular magnetic frame supported by the cross-bars or brackets B, provided with 60 feet C, upon which the machine rests. The interior of the annulus A is provided with a large number of projections or pole-pieces D. These may be formed or applied in a variety of ways—as, for example, by milling transverse grooves E.

Owing to the very large number and small size of the poles and the spaces between them, I apply the exciting or field coils by winding an insulated conductor F zigzag through the grooves, as shown in Fig. 5, carrying said wire around the annulus to form as many layers as is desired. In this way the pole-pieces D will be energized with alternately opposite polarity around the entire ring.

For the armature I employ a spider or circular frame G on a driving-shaft H, mounted in bearings in the brackets B. This spider carries a ring J, turned down, except at its edges, to form a trough-like receptacle for a mass of fine annealed iron wires K, which are wound in the groove to form the core proper for the armature-coils. Pins L are set in the sides of the ring J, and the coils M are wound over the periphery of the armature-structure and around the pins. The coils M are connected together in series, and these terminals N carried through the hollow shaft H to contact-rings P, from whence the currents are taken off by brushes O. In this way a machine with a very large number of poles may be constructed. It is easy, for instance, to obtain in this manner three hundred and seventy-five to four hundred poles in a machine that may be safely driven at a speed of fifteen hundred or sixteen hundred revolutions per minute, which will produce ten thousand or eleven thousand alternations of current per second.

Arc lamps R R are shown in diagram as connected up in series with the machine in Fig. 2. If such a current be applied to running arc lamps, the sound produced by or in the arc becomes practically inaudible, for by increasing the rate of change
in the current, and consequently the number of vibrations per unit of time of the gaseous material of the arc up to or beyond ten thousand or eleven thousand per second, or to what is regarded as the limit of audition, the sound due to such vibrations will not be audible. The exact number of changes or undulations necessary to produce this result will vary somewhat according to the size of the arc—that is to say, the smaller the arc the greater the number of changes that will be required to render it inaudible within certain limits. Of course, as the rate of alternations or undulations for a given size of arc becomes very high the sound produced is less perceptible, and hence for some purposes the actual limit of audition may only be approached, provided the sound be rendered practically inaudible.

Another advantage gained by increasing as above set forth the number of alternations is that the arc acts more like that produced by a continuous current, in that it is more persistent, owing to the fact that the time interval between undulations is so small that the gaseous matter cannot cool down so far as to increase very considerably in resistance. I claim—

The method of abating or rendering inaudible the sound emitted by arc lamps supplied with or operated by an alternating or pulsating current by increasing the rate of such alternations or pulsations up to that of the limit of audition, as set forth.

NIKOLA TESLA.

Witnesses:
FRANK B. MURPHY,
RAPHAEL NETTER.
To all whom it may concern:

Be it known that I, NIKOLA TESLA, a citizen of the United States, residing at the borough of Manhattan, in the city of New York, county and State of New York, have invented certain new and useful Improvements in Apparatus for the Transmission of Electrical Energy, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

This invention is a division of an application filed by me on September 2, 1897, Serial No. 690,345, entitled "Systems of transmissions of electrical energy," and is based upon new and useful features and combinations of apparatus shown and described in said application for carrying out the method therein disclosed and claimed.

The invention which forms the subject of my present application comprises a transmitting coil or conductor in which electrical currents or oscillations are produced and which is arranged to cause such currents or oscillations to be propagated by conduction through the natural medium from one point to another remote therefrom and a receiving coil or conductor at such distant point adapted to be excited by the oscillations or currents propagated from the transmitter.

This apparatus is shown in the accompanying drawing, which is a diagrammatic illustration of the same.

A is a coil, generally of many turns and of a very large diameter, wound in spiral form either about a magnetic core or not, as may be desired. C is a second coil formed by a conductor of much larger size and smaller length wound around and in proximity to the coil A.

The apparatus at one point is used as a transmitter, the coil A in this case constituting a high-tension, secondary, and the coil C the primary, of much lower tension, of a transformer. In the circuit of the primary C is included a suitable source of current G. One terminal of the secondary A is at the center of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed or maintained by such means as a balloon at an elevation suitable for the purposes of transmission. The other terminal of the secondary A is connected to earth, and, if desired, to the primary also, in order that the latter may be at substantially the same potential as the adjacent portions of the secondary, thus insuring safety. At the receiving station a transformer of similar construction is employed; but in this case the longer coil A constitutes the primary, and the shorter coil C' the secondary, of the transformer. In the circuit of the latter are connected lamps L, motors M, or other devices for utilizing the current. The elevated terminal D' connects with the center of the coil A', and the other terminal of said coil is connected to earth and preferably, also, to the coil C' for the reasons above stated.

The length of the thin wire coil in each transformer should be approximately one-quarter of the wave length of the electric disturbance in the circuit, this estimate being based on the velocity of propagation of the disturbance through the coil itself and the circuit with which it is designed to be used. By way of illustration, if the rate at which the current traverses the circuit including the coil be one hundred and eighty-five thousand miles per second then a frequency of nine hundred and twenty-five per second would maintain nine hundred and twenty-five stationary moves in a circuit one hundred and eighty-five thousand miles long and each wave would be two hundred miles in length.

For such a low frequency, which would be resorted to only when it is indispensable for the operation of motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length. By such an adjustment or proportioning of the length of wire in the secondary coil or coils the points of highest potential are made to coincide with the elevated terminals D D', and it should be understood that whatever length be given to the wires this requirement should be complied with in order to obtain the best results.

It will be readily understood that when the above-prescribed relations exist the best conditions for resonance between the transmi-
ting and receiving circuits are attained, and
owing to the fact that the points of highest po-
tential in the coils or conductors A A' are
incident with the elevated terminals the
maximum flow of current will take place in
the two coils, and this, further, necessarily
implies that the capacity and inductance in
each of the circuits have such values as to
secure the most perfect condition of synchro-
nism with the impressed oscillations.

When the source of current G is in opera-
tion and produces rapidly pulsating or oscil-
lating currents in the circuit of coil C, cor-
responding induced currents of very much
higher potential are generated in the second-
ary coil A, and since the potential in the same
gradually increases with the number of turns
toward the center and the difference of poten-
tial between the adjacent turns is compara-
tively small a very high potential impracticable
with ordinary coils may be successively ob-
tained.

As the main object for which the apparatus
is designed is to produce a current of excess-
ively-high potential, this object is facilitated
by using a primary current of very consid-
erable frequency; but the frequency of the
currents is in a large measure arbitrary, for
if the potential be sufficiently high and the
terminals of the coils be maintained at the
proper elevation where the atmosphere is
rarified the stratum of air will serve as a con-
ducting medium for the current produced
and the latter will be transmitted through the
air, with, it may be, even less resistance than
through an ordinary conductor.

As to the elevation of the terminals D D', it
is obvious that this is a matter which will be
determined by a number of things, as by the
amount and quality of the work to be per-
formed, by the condition of the atmosphere,
and also by the character of the surrounding
country. Thus if there be high mountains
in the vicinity the terminals should be at a
greater height, and generally they should al-
ways be at an altitude much greater than that
of the highest objects near them. Since by
the method is brought practically any potential
that is desired may be produced, the currents
through the air strata may be very small, thus
reducing the loss in the air.

The apparatus at the receiving-station re-
news to the currents propagated from the
transmitter in a manner which will be well
understood from the foregoing description.

The primary circuit of the receiver—that is,
the thin wire coil A'—is excited by the cur-
cents propagated by conduction through the
intervening natural medium from the trans-
mmitter, and these currents induce in the sec-
ondary coil C' other currents which are util-
ized for operating the devices included in the
circuit thereof.

Obviously the receiving-coils, transfor-
ers, or other apparatus may be movable—as,
for instance, when they are carried by a ves-
sel floating in the air or by a ship at sea. In

the former case the connection of one termi-
nal of the receiving apparatus to the ground
might not be permanent, but might be inter-
mitently or inductively established without
departing from the spirit of my invention.

It is to be noted that the phenomenon here
involved in the transmission of electrical en-
ergy is one of true conduction and is not to
be confounded with the phenomena of elec-
trical radiation which have heretofore been
observed and which from the very nature and
mode of propagation would render practically
impossible the transmission of any appreci-
able amount of energy to such distances as
are of practical importance.

What I now claim as my invention is—
1. The combination with a transmitting coil
or conductor connected to ground and to an
elevated terminal respectively, and means for
producing therein electrical currents or oscil-
lations, of a receiving coil or conductor simi-
larly connected to ground and to an elevated
terminal, at a distance from the transmit-
ting-coil and adapted to be excited by cur-
cents caused to be propagated from the same
by conduction through the intervening nat-
ural medium, a secondary conductor in in-
ductive relation to the receiving-conductor
and devices for utilizing the current in the
circuit of said secondary conductor, as set
forth.

2. The combination with a transmitting coil
or conductor having its ends connected to
ground and to an elevated terminal respecti-
vately, a primary coil in inductive relation
thereto and a source of electrical oscillations
in said primary circuit, of a receiving conduc-
tor or coil having its ends connected to ground
and to an elevated terminal respectively and
adapted to be excited by currents caused to be
propagated from the transmitter through the
natural medium and a secondary circuit in inductive relation to the receiving-circuit
and receiving devices connected therewith,
as set forth.

3. The combination with a transmitting in-
strument comprising a transformer having its
secondary connected to ground and to an ele-
vated terminal respectively, and means for
impressing electrical oscillations upon its pri-
mary, of a receiving instrument comprising
a transformer having its primary similarly
connected to ground and to an elevated ter-

inal, and a translating device connected
with its secondary, the capacity and induc-
tance of the two transformers having such
values as to secure synchronism with the im-
pressed oscillations, as set forth.

4. The combination with a transmitting in-
strument comprising an electrical transfor-
meter having its secondary connected to
ground and to an elevated terminal respecti-
vately, and means for impressing electrical
oscillations upon its primary, of a receiving
instrument comprising a transformer having
its primary similarly connected to ground
and to an elevated terminal, and a translat-
ing device connected with its secondary, the capacity and inductance of the secondary of the transmitting and primary of the receiving instruments having such values as to secure synchronism with the impressed oscillations, as set forth.

5. The combination with a transmitting coil or conductor connected to ground and an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal and synchronized with the transmitting coil or conductor, as set forth.

10. The combination with a transmitting instrument comprising an electrical transformer, having its secondary connected to ground and to an elevated terminal respectively, of a receiving instrument comprising a transformer, having its primary similarly connected to ground and to an elevated terminal, the receiving-coil being synchronized with that of the transmitter, as set forth.

15. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and means for producing electrical currents or oscillations in the same, of a receiving coil or conductor similarly connected to ground and to an elevated terminal, the said coil or coils having a length equal to one-quarter of the wave length of the disturbance propagated, as set forth.

20. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively, and adapted to cause the propagation of currents or oscillations by conduction through the natural medium, of a receiving circuit similarly connected to ground and to an elevated terminal, and of a capacity and inductance such that its period of vibration is the same as that of the transmitter, as set forth.

25. The transmitting or receiving circuit herein described, connected to ground and an elevated terminal respectively, and arranged in such manner that the elevated terminal is charged to the maximum potential developed in the circuit, as set forth.

30. The combination with a transmitting coil or conductor connected to ground and to an elevated terminal respectively of a receiving-circuit having a period of vibration corresponding to that of the transmitting circuit and similarly connected to ground and to an elevated terminal and so arranged that the elevated terminal is charged to the highest potential developed in the circuit, as set forth.

NIKOLA TESLA.

Witnesses:

PARKER W. PAGE,

MARCELLUS BAILEY.
NIKOLA TESLA TELLS OF NEW RADIO THEORIES

An interview with Nikola Tesla

New York Herald Tribune, September 22, 1929

Does Not Believe in Hertz Waves and Heaviside Layer, Interview Discloses

The model of a "Tesla Coil" which will be featured in the historic exhibit of the radio show reawakens interest in its inventor.

It is not generally appreciated that this curious apparatus, often associated with pretty or spectacular demonstrations of high voltage electricity, is really a fundamental part of modern radio. For all the tuning apparatus and circuits in every transmitting and receiving set are simply variations of Tesla coils and Tesla coil circuits.

It was for this invention, and other inventions and principles concerned with tuning, heterodyning, and the generation of continuous waves, which were made at least several years before the very first experiments of Marconi, that many of our most reputable engineers have conceded to Nikola Tesla the title of "Father of Radio".

Mr. Tesla, still actively working, was interviewed last week to get his ideas regarding the prospects of the radio of 1930, and beyond. As a prophet, however, he balked. He had repeated time and again his visions for the future. As far back as 1900, he had contemplated a world-wireless system which included broadcasting, picture transmission, international time service, and in addition television and the distribution of electrical power. Part of this early prophecy has been realized - what remained, still stood as his prediction..

Disputes Hertz Waves

What, then, about power transmission by radio? Laurence M. Cockaday, the technical editor of this radio section, had expressed the opinion several weeks ago that, with present apparatus at least, it was hardly feasible. Mr. Tesla agreed to discuss the point at length. As a result, he made public for the first time one of the most extraordinary conclusions - that Hertz waves do not exist! If his theory is true, there may be found in it more adequate explanations of "dead spots", fading, reflection and a dozen other problems that have always puzzled the profession.

The inventor began by referring to Cockaday's article:

"I have read the article, and I quite agree with the opinion expressed - that wireless power transmission is impractical with present apparatus. This conclusion will be naturally reached by any one who recognizes the nature of the agent by which the impulses are transmitted in present wireless practice.

"When Dr. Heinrich Hertz undertook his experiments from 1887 to 1889 his object was to demonstrate a theory postulating a medium filling all space, called the ether, which was structureless, of inconceivable tenuity and yet solid and possessed of rigidity incomparably greater than that of the hardest steel. He obtained certain results and the whole world acclaimed them as an experimental verification of that cherished theory. But in reality what he observed tended to prove just its fallacy.

"I had maintained for many years before that such a medium as supposed could not exist, and that we must rather accept the view that all space is filled with a gaseous substance. On repeating the Hertz experiments with much improved and very powerful apparatus, I satisfied myself that what he had observed was nothing else but effects of longitudinal waves in a gaseous medium, that is to say, waves, propagated by alternate compression and expansion. He had observed waves in the ether much of the nature of sound waves in the air.
"Up to 1896, however, I did not succeed in obtaining a positive experimental proof of the existence of such a medium. But in that year I brought out a new form of vacuum tube capable of being charged to any desired potential, and operated it with effective pressures of about 4,000,000 volts. I produced cathodic and other rays of transcending intensity. The effects, according to my view, were due to minute particles of matter carrying enormous electrical charges, which, for want of a better name, I designated as matter not further decomposable. Subsequently those particles were called electrons.

"One of the first striking observations made with my tubes was that a purplish glow for several feet around the end of the tube was formed, and I readily ascertained that it was due to the escape of the charges of the particles as soon as they passed out into the air; for it was only in a nearly perfect vacuum that these charges could be confined to them. The coronal discharge proved that there must be a medium besides air in the space, composed of particles immeasurably smaller than those of air, as otherwise such a discharge would not be possible. On further investigation I found that this gas was so light that a volume equal to that of the earth would weigh only about one-twentieth of a pound.

"The velocity of any sound wave depends on a certain ratio between elasticity and density, and for this ether or universal gas the ratio is 800,000,000,000 times greater than for air. This means that the velocity of the sound waves propagated through the ether is about 300,000 times greater than that of the sound waves in air, which travel at approximately 1,085 feet a second. Consequently the speed in ether is 900,000 x 1,085 feet, or 186,000 miles, and that is the speed of light.

"As the waves of this kind are all the more penetrative the shorter they are, I have for years urged the wireless experts to use such waves in order to get good results, but it took a long time before they settled upon this practice.

"Although the world is still skeptical as to the feasibility of my undertaking, I note that some advanced experts, at least, share my views, and I hope that before long wireless power transmission will be as common as transmission by wires."

According to Mr. Tesla, the present broadcasting station does not propagate Hertzian waves, as has always been supposed, but acts more like an "ether whistle" - transmitting waves through the ether similar to the waves transmitted by an ordinary whistle through the air. He also expressed his disbelief in the Heaviside layer, and claimed that the reflection of waves back toward the earth was due to the change of medium encountered at the vacuous boundary of the atmosphere.

At Colorado Springs, about thirty years ago, this scientist had a Tesla coil seventy-five feet in diameter which produced voltages above 12,000,000, and sparks over 100 feet long. Electrical flashes were created which were the nearest approach to lightning that man has ever made. During his experiments there, of over a year, Tesla claims that he transmitted a considerable amount of electrical current to the other side of the earth. It was upon these, and later experiments that he bases his present prediction.
NIKOLA TESLA'S WIRELESS WORK

By Frank Germano

Earth's Conductivity

Based upon a series of experiments conducted between 1888 and 1907 Tesla concluded that the earth is an excellent electrical conductor. He believed an electric current could propagate to terrestrial distances of thousands of miles "without diminution of intention," and made observations that, he felt, supported this supposition. He also found that Earth's naturally existing electrical charge can be made to oscillate, and that "by impressing upon it current waves [i.e., surface waves] of certain lengths, definitely related to its diameter, the globe is thrown into resonant vibration like a wire, forming stationary waves."

Its singleness is only an apparent limitation, for by impressing upon it numerous non-interfering vibrations, the flow of energy may be directed through any number of paths which, though bodily connected, are yet perfectly distinct and separate like ever so many cables. Any apparatus, then, which can be operated through one or more wires, at distances obviously limited, can likewise be worked without artificial conductors, and with the same facility and precision, at distances without limit other than that imposed by the physical dimensions of the globe.

It is intended to give practical demonstrations of these principles with the plant illustrated. . . . dictate instructions, and have them instantly appear in type elsewhere . . . talk to any telephone subscriber on the globe . . . hear anywhere music or song, speech . . . picture, character, drawing, or print transferred from one to another place . . . millions of instruments operated from one plant . . . transmission of power shown . . . ["The Future of the Wireless Art" Wireless Telegraphy & Telephony, Walter W. Massie & Charles R. Underhill, 1908, pp. 67-71]

Tesla felt the resistance of the Earth would be negligible due to its immense cross sectional area and relative shortness as compared to its diameter. (Corum & Corum) The key to good performance is a robust ground connection.

A [conducting] sphere of the size of a little marble offers a greater impediment to the passage of a current than the whole earth. . . . This is not merely a theory, but a truth established in numerous and carefully conducted experiments. [ibid]

. . . You must first understand certain things. Consider, for instance, the term "resistance." When you think of resistance you imagine, naturally, that you have a long, thin conductor; but remember that while resistance is directly proportionate to length, it is inversely proportionate to the section. It is a quality that depends on a ratio. If you take a small sphere of the same size of a pea, and compare its length with its section, you would find a certain resistance. Now you extend this pea to the size of the earth, and what is going to happen?

While the length increases, say a thousand times or a million times, the section increases with the square of the linear dimensions, so that the bigger this thing is the less resistance it has. Indeed, if the earth were as big as the sun we would still be better off than we are; we could readily telephone from one end of the sun to the other by the system, and the larger the planet the better it would be. . . . The resistance is only at the point where you get into the earth with your current. The rest is nothing. [Nikola Tesla On His Work With Alternating
Surface Waves

In 1916 Tesla stated in regards to the disposition of the “vibratory energy” of the oscillator, By proper design and choice of wavelengths, you can arrange it so that you get, for instance, 5 percent in these electromagnetic waves and 95 percent in the current that goes through the earth. That is what I am doing. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 132]

Tesla often spoke of the electrical disturbance being in the form of an electrical current flowing through the earth. As with any electrical current flowing through a conductor surrounded by an insulating medium, there is also an electrical disturbance in the material or space adjacent to that conductor. In the case of the World System, this is a surface wave traveling along the interface between the ground and the air. The wave energy is associated with the ground current. It does not radiate freely into space but tends to be concentrated near the surface of the conductor, i.e., the guiding surface. This is equivalent to the fields associated with an electrical current flowing in a wire.

126 x-Q. In this system, then, as you have described it, the current actually flows from the transmitter through the ground to the receiver; is that so?
Yes, sir; it does, in accordance with my understanding. In my Patent No. 649,621, “Apparatus for Transmission of Electrical Energy,” [May 15, 1900] it is stated distinctly: “It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of true conduction and is not to be confounded with the phenomena of electrical radiation, etc.”

The attractive feature of this plan was that the intensity of the signals should diminish very little with the distance, and, in fact, should not diminish at all, if it were not for certain losses occurring, chiefly in the atmosphere. [Nikola Tesla: Guided Weapons & Computer technology, Leland Anderson, Twenty First Century Books, p. 82]

Atmospheric Conductivity

The point-to-point type-one “air-ground system” depends upon passage of electrical current through both the earth and the atmosphere. To accommodate this, the Wardenclyffe-type World System transmitter/receiver facility includes both an air and a ground connection, each being called a “terminal.” Tesla clearly specified the earth as being one of the conducting media involved in ground and air system technology. The other specified medium is the atmosphere above 5 miles elevation. While not an ohmic conductor, in this region of the troposphere and upwards, the density or pressure is sufficiently reduced to so that, according to Tesla’s theory, the atmosphere’s insulating properties can be easily impaired, allowing an electric current to flow. His theory further states that the conducting region is developed through the process of atmospheric ionization, in which the effected portions thereof are changed to plasma. The presence of the magnetic fields developed by each plant’s helical resonator suggests that an embedded magnetic field and flux linkage is also involved. Flux linkage with Earth’s natural magnetic field is also a possibility.

The atmosphere below 5 miles is also viewed as a propagating medium for a portion of the aboveground circuit, and, being an insulating medium, electrostatic induction would be involved rather than true electrical conduction. Tesla felt that with a sufficiently high electrical potential on the elevated terminal the practical limitation imposed upon its height could be overcome. He anticipated that a highly energetic transmitter, as was intended at Wardenclyffe, would charge the elevated terminal to the point where the atmosphere around and above the facility would
break down and become ionized, leading to a flow of true conduction currents between the two terminals by a path up to and through the troposphere, and back down to the other facility. The ionization of the atmosphere directly above the elevated terminals could be facilitated by the placement of a projection at the apex of the elevated terminal. Such projections are routinely used by Tesla coil builders to create a directed discharge. Alternatively, an ionizing beam of ultraviolet radiation could be used to form what might be called a high-voltage plasma transmission line.

In 1935 Tesla spoke about the transmission of propulsive power to ships at sea "through the stratosphere" using this technique.

The principles of this high tension power, generated by shore plants and transmitted through the upper reaches of the air, illuminating the sky, turning night into day and at the same time supplying power, have occupied Dr. Tesla's attention on and off now for the past thirty-five years.

There is a method of conveying great power to ships at sea which would be able to propel them across oceans at high speed.

The principle is this. A ray of great ionizing power is used to give to the atmosphere great powers of conduction. A high tension current of 10,000,000 to 12,000,000 volts is then passed along the ray to the upper strata of the air, which strata can be broken down very readily and will conduct electricity very well.

A ship would have to have equipment for producing a similar ionizing ray. The current which has passed through the stratosphere will strike this ray, travel down it and pass into the engines which propel the ship. ["Faster Liners is Tesla's Dream," New York Sun, June 5, 1935]

A minimal type-one system would be composed of two identical type-one facilities. Each would be capable of acting as a transmitter or a receiver, i.e. each could serve as either an energy source or as a load. The net flow of energy between the two plants would be dictated by the phase relationship between them and the relative level of activity. There would be two elevated terminals, one at each facility. The atmospheric path passes high potential, low current electrical energy through a somewhat resistive plasma transmission line running the entire distance between the two elevated terminals. Conversely, the low-resistance ‘ground’ path passes electrical energy of low potential and high current, flowing through the body of the earth.

It is well known, the higher the voltage that is passed across a conventional electrical power transmission line, the greater is its efficiency. This is due to the relationship between voltage and current as they pertain to power dissipation. For example, to power a hypothetical 100-watt load, the current can be one ampere at 100 volts, 10 amperes at 10 volts or 100 amperes at 1 volt, or any number of similar combinations. Every conductor, other than a superconductor, has a finite resistance. The voltage drop (E) across a resistance (R) is given by Ohm's law, \( E = IR \). For any given load, with a constant transmission-line resistance, by lowering the current (I) that flows through the transmission line, the voltage drop or loss is reduced. As can be seen by the inverse relationship between voltage and current, increasing the transmission-line voltage reduces the current. Conversely, the greater the current involved in powering a given load, the greater is the transmission-line loss, taken as a function of transmission-line resistance.

The above statements about transmission-line loss are also true in regards to the plasma transmission line that runs between the two elevated terminals. Tesla designed his transmitter with the expressed purpose of developing the greatest possible potential on the elevated terminal in order to minimize the loss due to the plasma transmission-line resistance. Looking at the Tesla type-one wireless energy transmission system, each of the two transmitter-receiver facilities serve, in a sense, as a lever and a fulcrum for conversion of the electrical energy flowing across the two different conducting paths. [Corum & Corum]
by such means as have been described practically any potential that is desired may be
obtained, the currents through the air strata may be rendered very small, whereby the loss in
the transmission may be reduced. [System of Transmission of Electrical Energy, U.S. Patent
No. 645,576, Mar. 20, 1900]

The influence of resistance on transmission line efficiency depends upon the impedance of the
source and the load. For example, if a power supply puts out one watt, but puts it out at one
volt and one amp, then the output impedance of the source is one ohm. (R = E/I) The
transmission line had better have much less resistance than one ohm (say 0.1 ohm or smaller)
otherwise a significant portion of the transmitted energy will go into heating of the wire. In
other words, the one volt, one amp source thinks the division between conductor and insulator is
centered at the value of one ohm. A 100-ohm leakage path is nearly an insulator, since it
dissipates only 1% of the output wattage. Now suppose the power supply puts out one watt at
one kilovolt and one milliamp. In that case the source impedance is one megaohm, and the
connecting wires had better be 100K or less in resistance. In this case a 10K resistor is a
conductor of negligible resistance, and a one-megaohm leakage path will eat up half of
the power supply's output.

Applying this relationship to a type-one Tesla coil transmission system, if the transmitter puts
out one megawatt at one megavolts and one amp, then 100K is a fairly good conductor, and
insulators have to measure 10 megaohms or better. In this case, if you could create a vertical
plasma transmission line, and if the plasma filament measured 10 kilo-ohm, it would only
consume 1% of the transmitter's power output. If the potential of transmitter's elevated terminal
is raised to 100 megavolts at 10 mA (this is still 1 megawatt), then the supply impedance is
10,000 megaohms, and the plasma transmission line will act as a negligible series resistance
even if its resistance is 100 megaohms. [The two preceding paragraphs are based upon an
original text by William Beaty]

It was about 1896 when Tesla discovered that with a sufficiently high potential on the terminal
plate (P1) he could modify the properties of the air in the vicinity of his apparatus, changing it
from an insulator to a conductor

Up to the end of 1896, I had been developing the wireless system along the lines
set forth in my lecture which is in the Martin book, particularly in the chapter on
Electrical Resonance, pages 340-349. . . . But in experimenting with these high
potential discharges which I was always producing, I discovered a wonderful
thing. I found, namely, that the air, which had been behaving before like an
insulator, suddenly became like a conductor; that is, when subjected to these
great electrical stresses, it broke down and I obtained discharges which were not
accountable for by the theory that the air was an insulator. When I calculated the
effects, I concluded that this must be due to the potential gradient at a distance
from the electrified body, and subsequently I came to the conviction that it would
be ultimately possible, without any elevated antenna—with very small
elevation—to break down the upper stratum of the air and transmit the current by
conduction. [Nikola Tesla On His Work With Alternating Currents and Their
Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 125]

Tesla described this effect as observed at the Colorado Springs Experimental Station in the
patent “System of Transmission of Electrical Energy.”

. . . In illustration of these facts a few observations, which I have made with apparatus
devised for the purposes here contemplated, may be cited. For example, a conductor or
terminal, to which impulses such as those here considered are supplied, but which is
otherwise insulated in space and is remote from any conducting-bodies, is surrounded by
a luminous flame-like brush or discharge often covering many hundreds or even as much
as several thousands of square feet of surface, this striking phenomenon clearly attesting
the high degree of conductivity which the atmosphere attains under the influence of the
immense electrical stresses to which it is subjected. This influence is however, not
confined to that portion of the atmosphere which is discernible by the eye as luminous and which, as has been the case in some instances actually observed, may fill the space within a spherical or cylindrical envelop of a diameter of sixty feet or more, but reaches out to far remote regions, the insulating qualities of the air being, as I have ascertained, still sensibly impaired at a distance many hundred times that through which the luminous discharge projects from the terminal and in all probability much farther. The distance extends with the increase of the electromotive force of the impulses, with the diminution of the density of the atmosphere, with the elevation of the active terminal above the ground, and also, apparently, in slight measure, with the degree of moisture contained in the air. I have likewise observed that this region of decidedly-noticeable influence continuously enlarges as time goes on, and the discharge is allowed to pass not unlike a conflagration which slowly spreads, this being possibly due to the gradual electrification or ionization of the air or to the formation of less insulating gaseous compounds. It is, furthermore, a fact that such discharges of extreme tensions, approximating those of lightning, manifest a marked tendency to pass upward away from the ground, which may be due to electrostatic repulsion, or possibly to slight heating and consequent rising of the electrified or ionized air. These latter observations make it appear probable that a discharge of this character allowed to escape into the atmosphere from a terminal maintained at a great height will gradually leak through and establish a good conducting-path to more elevated and better conducting air strata, a process which possibly takes place in silent lightning discharges frequently witnessed on hot and sultry days. It will be apparent to what an extent the conductivity imparted to the air is enhanced by the increase of the electromotive force of the impulses when it is stated that in some instances the area covered by the flame discharge mentioned was enlarged more than sixfold by an augmentation of the electrical pressure, amounting scarcely to more than fifty per cent. As to the influence of rarefaction upon the electric conductivity imparted to the gases it is noteworthy that, whereas the atmospheric or other gases begin ordinarily to manifest this quality at something like seventy-five millimeters barometric pressure with the impulses of excessive electromotive force to which I have referred, the conductivity, as already pointed out, begins even at normal pressure and continuously increases with the degree of tenuity of the gas, so that at, say, one hundred and thirty millimeters pressure, when the gases are known to be still nearly perfect insulators for ordinary electromotive forces, they behave toward electromotive impulses of several millions of volts, like excellent conductors, as though they were rarefied to a much higher degree.

He was ionizing the air and creating plasma, which is electrically conductive. In light of this new understanding, he began to develop an alternative to the type-two-transmitter plan by which he might achieve wireless energy transmission.

Having discovered that, I established conditions under which I might operate in putting up a practical commercial plant. When the matter came up in the patents before the Examiner, I arranged this experiment for him in my Houston Street laboratory. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 126]
Tesla's diagram representing the arrangement of apparatus as demonstrated to G.D. Seeley.

This is a diagram representing the arrangement of apparatus as in a practical experiment which I performed before G.D. Seeley, Examiner in Chief, U.S. Patent Office, on the 23rd of January, 1898. This experiment illustrates a great departure I had made a little prior to that date. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 125]

Tesla's demonstration for the U.S. Patent Office, on January 23, 1898, at his Houston St. laboratory in New York City, was to show of the practicability of transmission of electrical energy in industrial amounts by the method and apparatus described in “System of Transmission of Electrical Energy,” U.S. Patent No. 645,576, dated March 20, 1900 and “Apparatus for Transmission of Electrical Energy,” U.S. Patent No. 649,621, dated May 15, 1900. The applications for both patents were filed September 2, 1897. [These are the initial patents specifically covering Tesla's wireless system.]

In 1898 I made certain demonstrations before the Examiner-in-Chief of the Patent Office, Mr. Seeley, and it was upon showing him the practicability of the transmission that patents were granted to me. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 27]

It might be argued the Colorado Springs experiments also served to demonstrate the technology in advance of patent issuance. The above-mentioned patents are dated March 20 and May 15, 1900, about 7 months after Tesla's return to New York. The Wardenclyffe project served to further demonstrate and refine the method and apparatus, as described in the U.S. Patents “Art of Transmitting Electrical Energy Through the Natural Mediums,” No. 787,412, April 18, 1905 and “Apparatus for Transmitting Electrical Energy,” No. 1,119,732, December 1, 1914.

Earth Resonance

Tesla's “World System” for wireless telegraphy, telephony and transmission of power was also to apply the principle of earth resonance.
If ever we can ascertain at what period the earth’s charge, when disturbed, oscillates with respect to an oppositely electrified system or known circuit, we shall know a fact possibly of the greatest importance to the welfare of the human race. I propose to seek for the period by means of an electrical oscillator, or a source of alternating electric currents. One of the terminals of the source would be connected to earth as, for instance, to the city water mains, the other to an insulated body of large surface. It is possible that the outer conducting air strata, or free space, contain an opposite charge and that, together with the earth, they form a condenser of very large capacity. In such case the period of vibration may be very low and an alternating dynamo machine might serve for the purpose of the experiment. I would then transform the current to a potential as high as it would be found possible and connect the ends of the high tension secondary to the ground and to the insulated body. By varying the frequency of the currents and carefully observing the potential of the insulated body and watching for the disturbance at various neighboring points of the earth’s surface resonance might be detected. Should, as the majority of scientific men in all probability believe, the period be extremely small, then a dynamo machine would not do and a proper electrical oscillator would have to be produced and perhaps it might not be possible to obtain such rapid vibrations. But whether this be possible or not, and whether the earth contains a charge or not, and whatever may be its period of vibration, it certainly is possible—for of this we have daily evidence—to produce some electrical disturbance sufficiently powerful to be perceptible by suitable instruments at any point of the earth’s surface. [ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA, Inventions, Researches and Writings of Nikola Tesla, 1894, p. 347.]

. . . It was clear to me from the very start that the successful consummation could only be brought about by a number of radical improvements. Suitable high frequency generators and electrical oscillators had first to be produced. The energy of these had to be transformed in effective transmitters and collected at a distance in proper receivers. Such a system would be manifestly circumscribed in its usefulness if all extraneous interference were not prevented and exclusiveness secured. In time, however, I recognized that devices of this kind, to be most effective and efficient, should be designed with due regard to the physical properties of this planet and the electrical conditions obtaining on the same.. ["The True Wireless” Electrical Experimenter, May 1919]

When the earth is struck mechanically, as is the case in some powerful terrestrial upheaval, it vibrates like a bell, its period being measured in hours. When it is struck electrically, the charge oscillates, approximately, twelve times a second. By impressing upon it current waves of certain lengths, definitely related to its diameter, the globe is thrown into resonant vibration like a wire, stationary waves forming, the nodal and ventral regions of which can be located with mathematical precision. Owing to this fact and the spheroidal shape of the earth, numerous geodetical and other data, very accurate and of the greatest scientific and practical value, can be readily secured. Through the observation of these astonishing phenomena we shall soon be able to determine the exact diameter of the planet, its configuration and volume, the extent of its elevations and depressions, and to measure, with great precision and with nothing more than an electrical device, all terrestrial distances. In the densest fog or darkness of night, without a compass or other instruments of orientation, or a timepiece, it will be possible to guide a vessel along the shortest or orthodromic path, to instantly read the latitude and longitude, the hour, the distance from any point, and the true speed and direction of movement. By proper use of such disturbances a wave may be made to travel over the earth’s surface with any velocity desired, and an electrical effect produced at any spot which can be selected at will and the geographical position of which can be closely ascertained from simple rules of trigonometry. [“The Future of the Wireless Art” 1908]

In fact, Tesla proposed two different methods by which global wireless energy transmission might be achieved. The first is by atmospheric conduction using two type-one facilities as described in the previous section. The second involves the use of earth resonance principles, the creation of manmade oscillations in Earth’s naturally existing electrical charge. This was
made clear in a 1932 interview in which he makes a distinction between the transmission of electrical energy by ionization of the upper atmosphere and terrestrial resonance.

I also asked him if he is still at work on the project which he inaugurated in the '90's of transmitting power wirelessly anywhere on earth. He is at work on it, he said, and it could be put into operation. . . . He at that time announced two principles which could be used in this project. In one the ionizing of the upper air would make it as good a conductor of electricity as a metal [using a type-one transmitter in conjunction with an active receiver]. In the other the power would be transmitted by creating "standing waves" in the earth by charging the earth with a giant electrical oscillator [of the type-two design] that would make the earth vibrate electrically in the same way a bell vibrates mechanically when it is struck with a hammer. "I do not use the plan involving the conductivity of the upper strata of the air," he said, "but I use the conductivity of the earth itself, and in this I need no wires to send electrical energy to any part of the globe." [Tesla Cosmic Ray Motor May Transmit Power 'Round Earth Brooklyn Eagle, July 10, 1932, John J. A. O'Neill]

The earth resonance method has basis in the one-wire transmission principles spoken of in the 1893 lecture ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA (see More on One-wire Transmission above.) It is described in U.S Patent No. 787,412, "ART OF TRANSMITTING ELECTRICAL ENERGY THROUGH THE NATURAL MEDIUMS." Here are some statements regarding "... improvement in the art of transmitting electrical energy to a distance which consists in establishing stationary electrical waves in the earth, . . ." contained in the similar Canadian patent:

... electrical disturbances may be transmitted through portions of the earth by grounding only one of the poles of the source. . . . Earth . . . behave[s] . . . much like a vast reservoir or ocean, which, while it may be locally disturbed by a commotion of some kind remains unresponsive and quiescent in a large part or as a whole. . . . When electrical waves or oscillations are impressed upon . . . a metallic wire, reflection takes place under certain conditions from the end of the wire, and in consequence of the interference of the impressed and reflected oscillations the phenomenon of "stationary waves" with maxima and minima in definite fixed positions is produced. . . . The terrestrial globe may in a large part or as a whole behave toward disturbance impressed upon it in the same manner as a conductor of limited size. . . .

In . . . studying the effects of lightning discharges upon the electrical condition of the earth I observed . . . electrical waves which were produced in the earth and which had nodal regions following at definite distances the shifting source of the disturbances. From data obtained in a large number of observations of these waves I found their length to vary approximately from twenty-five to seventy kilometre and these results and certain theoretical deductions led me to the conclusion that waves of this kind may be of still more widely differing lengths, the extreme limits being imposed by the physical dimensions and properties of the earth.

Figure 1 represents diagrammatically the generator which produces stationary waves in the earth, and Fig. 2 an apparatus situated in a remote locality for recording the effects of these waves.

In Fig. 1, A designates a primary coil forming part of a transformer and consisting generally of a few turns of a stout cable of inappreciable resistance, the ends of which are connected to the terminals of a source of powerful electrical oscillations, diagrammatically represented by D. This source is usually a condenser charged to a high potential and discharged in rapid succession through the primary, as in a type of transformer invented by me and now well known; but when it is desired to produce stationary waves of great lengths an alternating dynamo of suitable construction may be used to energize the primary A. . . . the total length of the conductor, from the ground-plate E to the elevated terminal D should be equal to one-quarter of the wave length of the electrical disturbance in the system E C D or else equal to that length multiplied by an odd
number. This relation being observed, the terminal D will be made to coincide with the points of maximum pressure in the secondary or excited circuit, and the greatest flow of electricity will take place in the same. In order to magnify the electrical movement in the secondary as much as possible, it is essential that its inductive connection with the primary A should not be very intimate, as in ordinary transformers, but loose, so as to permit free oscillation. . . The spiral form of coil C secures this advantage. The powerful electrical oscillations in the system E C D being communicated to the ground cause corresponding vibrations to be propagated to distant parts of the globe, whence they are reflected and by interference with the outgoing vibrations produce stationary waves the crests and hollows of which lie in parallel circles relatively to which the ground–plate E may be considered to be the pole. Stated otherwise, the terrestrial conductor is thrown into resonance with the oscillations impressed upon it just like a wire. Three requirements seem to be essential to the establishment of the resonating condition.

First. The earth’s diameter passing through the pole should be an odd multiple of the quarter wave length – that is, of the ratio between the velocity of light – and four times the frequency of the currents.

\[ M = \frac{D}{\lambda} = \frac{D}{\frac{1}{4} \lambda} \]

\[ \lambda = \frac{c}{f} = 4D/M \]

\[ C = \text{speed of light at 299,792 km/sec.} \]

\[ D = \text{Earth diameter at 12,742 km.} \]

\[ M = \text{odd multiple at 1} \]

The resonant frequency is therefore given to be: \[ f = \frac{M \times C}{4D} = 5.881965 \] (Yost)

The resonant frequency based upon round-trip time: \[ f = \frac{2(M \times C)}{4D} = 11.76393 \]

Second. It is necessary to employ oscillations in which the rate of radiation of energy into space in the form of hertzian or electromagnetic waves is very small . . . say smaller then twenty thousand per second, though shorter waves might be practicable. The lowest frequency would appear to be six per second, in which case there will be but one node, at or near the ground-plate . . .

Third. . . . irrespective of frequency the wave or wave-train should continue for a certain interval of time, estimated to be not less then one-twelfth or probably 0.08484 of a second and which is taken in passing to and returning from the region diametrically opposite the pole . . .

The presence of the stationary waves may be detected in many ways. For instance, a circuit may be connected directly or inductively to the ground and to an elevated terminal and tuned to respond more effectively to the oscillations. Another way is to connect a tuned circuit to the ground at two points lying more or less in a meridian passing through the pole E or, generally stated, to any two points of a different potential. The specific plan of producing the stationary waves, here-in described, might be departed from. For example, the circuit which impresses the powerful oscillations upon the earth might be connected to the latter at two points [a type-two transmitter]. In collecting the energy of these disturbances in any terrestrial region at a distance from their source, . . . the most economical results will be generally secured by the employment of my synchronized receiving transformer.

To complete this description, it may be stated that when it is desired to operate, independently, a great many receiving devices, by such stationary waves of different length, the principles which I have set forth in my British patent 14,579 [1901] and in my United States patents Nos. 723,188 and 725,605 [1903] may be
resorted to for rendering the signals or quantities of energy intended for any particular receiver or receivers non-interfering and non-interferable.

Related statements from Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power:

To give you an idea, I have prepared a diagram illustrating an analogue which will clearly show how the current passes through the globe. You know that in a solar eclipse the moon comes between the sun and the earth, and that its shadow is projected upon the earth's surface. Evidently, in a given moment, the shadow will just touch at a mathematical point, the earth, assuming it to be a sphere.

![Diagram illustrating the mode of propagation of the current from the transmitter over the earth's surface.](image)

Let us imagine that my transmitter is located at this point, and that the current generated by it now passes through the earth. It does not pass through the earth in the ordinary acceptance of the term, it only penetrates to a certain depth according to the frequency. Most of it goes on the surface, but with frequencies such as I employ, it will dive a few miles below. It can be mathematically shown that it is immaterial how it passes; the aggregate effect of these currents is as if the whole current passes from the transmitter, which I call the pole, to the opposite point, which I call the antipode. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, pp. 137-138]

The phrase “a few miles below” gives the earth current propagation model a minimum skin depth of 3 miles, 15,850 feet, or 4,828 meters.

Assume, then, that here is the transmitter, and imagine that this is the surface of the sea, and that now comes the shadow of the moon and touches, on a mathematical point, the calm ocean. You can readily see that as the surface of the water, owing to the enormous radius of the earth, is nearly a plane, that point where the shadow falls will immediately, on the slightest motion of the shadow downward, enlarge the circle at a terrific rate, and it can be shown mathematically that this rate is infinite. In other words, this half-circle on this side will fly over the globe as the shadow goes down; will first start at infinite velocity to enlarge, and then slower and slower and slower, and as the moon's shadow goes further and further and further, it will get slower and slower until, finally, when the three bodies are on the plane of the ecliptic, right in line one with the other in the same plane, then that shadow will pass over the globe with its true velocity in space. Exactly that same thing happens in the application of my system, and I will show this next.

This illustrates, on a larger scale, the earth. Here is my transmitter -- mine or anybody's transmitter -- because my system is the system of the day. The only difference is in the way I apply it. They, the radio engineers, want to apply my system one way; I want to apply it in another way. This is the circuit energizing the antenna. As the vibratory energy flows, two things happen: There is electromagnetic energy radiated and a current passes into the earth. The first goes out in the form of rays, which have definite properties. These rays propagate with the velocity of light, 300,000 kilometers per second. This energy is exactly like a hot stove. If you will imagine that the cylinder antenna is hot -- and indeed it is heated by the current -- it would radiate out energy of exactly the same kind as it does now. If the system is applied in the sense I want to apply it, this energy is absolutely lost, in all cases most of it is lost. While this electromagnetic energy throbs, a current passes into the globe.

Now, there is a vast difference between these two, the electromagnetic and current energies. That energy which goes out in the form of rays, is, as I have indicated here, unrecoverable, hopelessly lost. You can operate a little instrument by catching a billionth part of it but, except this, all goes out into space never to return. This other energy, however, of the current in the globe, is stored and completely recoverable. Theoretically, it does not take much effort to maintain the earth in electrical vibration. I have, in fact, worked out a plant of 10,000 horse-power which would operate with no bigger loss than 1 percent of the whole power applied; that is, with the exception of the frictional energy that is consumed in the rotation of the engines and the heating of the conductors, I would not lose more than 1 percent. In other words, if I have a 10,000 horsepower plant, it would take only 100 horsepower to keep the earth vibrating so long as there is no energy taken out at any other place.

There is another difference. The electromagnetic energy travels with the speed of light, but see how the current flows. At the first moment, this current
propagates exactly like the shadow of the moon at the earth’s surface. It starts with infinite velocity from that point, but its speed rapidly diminishes; it flows slower and slower until it reaches the equator, 6,000 miles from the transmitter. At that point, the current flows with the speed of light -- that is, 300,000 kilometers per second. But, if you consider the resultant current through the globe along the axis of symmetry of propagation, the resultant current flows continuously with the same velocity of light.

Whether this current passing through the center of the earth to the opposite side is real, or whether it is merely an effect of these surface currents, makes absolutely no difference. To understand the concept, one must imagine that the current from the transmitter flows straight to the opposite point of the globe.

There is where I answer the attacks which have been made on me. For instance, Dr. Pupin has ridiculed the Tesla system. He says, "The energy goes only in all directions." It does not. It goes only in one direction. He is deceived by the size and shape of the earth. Looking at the horizon, he imagines how the currents flow in all directions, but if he would only for a moment think that this earth is like a copper wire and the transmitter on the top of the same, he would immediately realize that the current only flows along the axis of the propagation.

The mode of propagation can be expressed by a very simple mathematical law, which is, the current at any point flows with a velocity proportionate to the cosecant of the angle which a radius from that point includes with the axis of symmetry of wave propagation. At the transmitter, the cosecant is infinite; therefore, the velocity is infinite. At a distance of 6,000 miles, the cosecant is unity; therefore, the velocity is equal to that of light. This law I have expressed in a patent by the statement that the projections of all zones on the axis of symmetry are of the same length, which means, in other words, as is known from rules of trigonometry, that the areas of all the zones must also be equal. It says that although the waves travel with different velocities from point to point, nevertheless each half wave always includes the same area. This is a simple law, not unlike the one which has been expressed by Kepler with reference to the areas swept over by the radii vectors.

I hope that I have been clear in this exposition – in bringing to your attention that what I show here is the system of the day, and is my system -- only the radio engineers use my apparatus to produce too much of this electromagnetic energy here, instead of concentrating all their attention on designing an apparatus which will impress a current upon the earth and not waste the power of the plant in an uneconomical process.

Counsel
You say radio engineers put too much energy into the radiating part. What, as a matter of fact, according to your conception, is the part of the energy that is received in the receivers in the present system?
Tesla
That has been investigated. Very valuable experiments have been made by Dr. Austin, who has measured the effects at a distance. He has evolved a formula in agreement with the Hertz wave theory, and the energy collected is an absolutely vanishing quantity. It is just enough to operate a very delicate receiver. If it were not for such devices as are now in use, the audion, for instance, nothing could be done. But with the audion, they magnify so that this infinitesimal energy they get is sufficient to operate the receiver. With my system, I can convey to a distant point millions of times the energy they transmit. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, pp. 136-142]
Terrestrial Resonances

It has been proposed that there are two forms of terrestrial resonance, Schumann resonance and (for lack of a better term) Earth resonance, both related to the diameter of the earth. Schumann resonance is studied by observing the effects of lightning discharges upon the electrical condition of the earth, specifically the naturally occurring electric and magnetic fields. Earth’s electrical condition can also be modified by artificial means, as did Tesla, by use of a properly tuned and configured electrical oscillator. The world’s AC power distribution systems do this more or less continuously, to a limited degree.

Schumann resonance:

Fundamental period of resonant oscillation: shifts between 7.5 - 7.9 Hz. (Anderson, Bradford)


Wave description: “cavity wave” (Yost), “surface wave” (Wasser)

Detection: buried 3-component magnetic field sensors & multiple component elevated electric field sensors

Earth resonance:

Fundamental period of resonant oscillation: 11.76393 (Yost), 11.79 Hz. (Wasser) *

Q: [unknown]

Wave description: “electrodynamic wave” (Sommerfeld), “conductor wave” (Yost) “pressure wave” (Wasser),

Detection: buried 3-component magnetic field sensors & buried 3-component electric potential gradient sensors

[*] Fundamental period of resonant oscillation based upon round-trip time.

Some harmonic of the fundamental earth resonant frequency—up to approximately 25 – 35 kHz—is used for the oscillator frequency. In this frequency range the around-the-world propagation efficiency is in the general area between 93 to 87%. As the frequency is increased above this point, efficiency further decreases. At 160 kHz the efficiency falls below 10%.

[Corum, K. L. and J. F. Corum, “Nikola Tesla, Lightning Observations and Stationary Waves,” Proceedings of the 1994 Colorado Springs Tesla Symposium, 1994, Appendix II, ”The Zenneck Surface Wave”] The oscillatory transformer provides the high voltage alternating current needed to periodically charge the transmitter’s elevated terminal. A monochromatic subcarrier signal is then added. This is in the form of an abrupt lower frequency electrical impulse applied at a rate approaching the fundamental earth resonance frequency. Higher frequency impulses, above the oscillator frequency are also added at every harmonic of the low frequency subcarrier impulse, be it the fundamental earth resonance frequency or some lower harmonic of same.

[Corum & Corum] While the following quote refers to the use of an RF alternator in conjunction with a resonance transformer to produce continuous waves, it appears to be applicable to the excitation of earth resonance modes as well.

I reduced the number of poles, I think, in 1901. But then I reduced it for the purpose of generating currents of higher frequency. If I had a great number of
poles, I could not realize my idea, because these poles would come in quick succession and not produce a rate of change comparable to the rate of change which is obtainable by the discharge of a condenser owing to a sudden break of the dielectric. That is to say, a blow. It has to be a blow, you see. I had to place my poles comparatively far apart, then run them at excessive speed and generate comparatively few impulses, but each of those impulses are of such tremendous intensity that the dynamo is practically short-circuited. That gave me a blow which replaced the arc. And then, of course, there remained to be perfected a scheme enabling me to get the energy of the alternator in the most economical manner, in high harmonics. That is not known, at least I have not seen anything of that kind in literature, and I believe that if anybody would attempt it without the devices which I have invented, he could not get much of the energy in high harmonics. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 15]

The system would be composed of two or more type-one transmitter/receiver signal-generating facilities, each contributing energy to the entire network to a greater or lesser degree. The resulting wave complex would be the combination of multiple electrical oscillations ranging from the fundamental earth resonance frequency or some low harmonic thereof, the oscillator frequency, and higher frequency impulses extending, possibly, to the upper limit of the radio frequency spectrum. The elevated terminal acting as an antenna might be capable of directly launching the higher frequency components of the wave complex as electromagnetic radiation, providing localized radio-frequency signal coverage. If true, this might provide an opportunity for locally originated programming that would be associated only with a local source or generator, to the exclusion of other signal-generating facilities operating on the same frequencies.

**Operating Frequencies**

At Wardenclyffe Tesla operated at frequencies from 1,000 Hz to 100 kHz. He found the frequency range up to 30 – 35 kHz, “to be most economical.” [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, pp. 143, 155] In operation, the system would have generated and sustained a wave complex . . .


For such a low frequency, to which I shall resort only when it is indispensable to operate motors of the ordinary kind under the conditions above assumed, I would use a secondary of fifty miles in length.
World System Apparatus

The Telecommunications Transmitting / Receiving Plant

Minimally implemented, a type-one transmission system requires two synchronized type-one electrical oscillators, each consisting of an appropriate radio-frequency power supply connected to the earth and a vertically oriented top-loaded helical resonator. In operation a pulsed electrical potential is applied to each of the two helical resonators creating, at each location, an oscillating magnetic field. In turn, each oscillating magnetic field induces an oscillating electric field. Together the oscillating electric and magnetic fields create weakly to highly ionized plasma in the vicinity of each resonator. [If the two resonators have a 180deg phase relationship with each other they are optimally aligned for connection of their respective magnetic fields.] In addition to the inductively coupled discharge created plasma, conditions also exist for the creation of capacitively coupled discharge plasma between the two respective elevated terminals. This is the “aurora” effect described by Tesla in the 1916 interview.

I have constructed and patented a form of apparatus which, with a moderate elevation of a few hundred feet, can break the air stratum down. You will then see something like an aurora borealis across the sky, and the energy will go to the distant place. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 110]

Each plant would be about the size of the Wardenclyffe prototype, with multiple resonators, a fixed elevated terminal and a high-power local oscillator. Each would have very wide bandwidth Internet and telephone network interfaces and be permanently connected with providers of radio and television programming.

The Electrical Power Distribution Plant

A grounded magnifying transmitter probably larger than the Wardenclyffe prototype with fewer resonators, a fixed elevated terminal plus a high-power local oscillator. Located near sources of energy such as large waterfalls, wind farms, solar power plants and developed sources of geothermal energy, also oil fields, coal mines, etc. May be comprised of two type-one transmitters in relatively close proximity to each other, forming a single type-two transmitter.

The Helical Resonator

The helical resonator is involved in making the above-ground portion of the launching structure resonant at the operating frequency but it is not an antenna-loading coil. [Corum & Corum] The coil is also involved in launching of the ‘current wave’, i.e., ground current and associated surface wave; (see Fritz Lowenstein, lecture before the IRE, 1915 (find it), Tesla Primer and Handbook, Ch. 2, Corum & Corum.)

The Elevated Terminal

The elevated terminal of a Tesla transmitter/receiver facility, referred to by some as an “isotropic capacitance,” does not exist in total isolation from the environment; it is coupled to its surroundings. According to the patent SYSTEM FOR TRANSMISSION OF ELECTRICAL ENERGY and Tesla’s article THE TRUE WIRELESS there is an interaction between the elevated terminals of the transmitter and the receiver facilities involving electrostatic induction and, in some cases, true electrical conduction through plasma. In operation the elevated terminal functions as one plate a capacitor. In opposition to the terminal is all other matter in the environment, especially on the earth’s surface, including the receiver’s elevated terminal. The terminal serves two purposes: first, in conjunction with the earth’s surface, especially in the locality of the transmitter, it acts as a charge reservoir. Secondly it is one of two capacitor plates, the other plate being the elevated terminal of the receiving facility, with which it acts in conjunction. In a high-power system they jointly act as a high voltage discharge terminals for the formation of capacitively coupled discharge plasma with interconnection taking place through the upper level atmosphere.

. . . The elevated terminal charged to a high potential induces an equal and opposite charge in the earth and there are thus Q lines giving an average current
I = 4Qn which circulates locally and is useless except that it adds to the momentum. A relatively small number of lines q however, go off to great distance and to these corresponds a mean current of Ie = 4qn to which is due the action at a distance. The total average current in the antenna is thus Im = 4Qn + 4qn and its intensity is no criterion for the performance. The electric efficiency of the antenna is q/Q+q and this is often a very small fraction. ["The True Wireless" Electrical Experimenter, May 1919]

Fig. 14. Diagram Explaining the Relation Between the Effective and the Measured Current In the Antenna.

In operation, a strong electrostatic field is produced around a Tesla transmitter/receiver facility. Field lines extend outward from the elevated terminal to come in contact with other objects in the environment. While more or less a majority of the field lines of a type-one transmitter are associated with nearby objects, some of them, in theory, are associated with the elevated terminal of the other plant.

The Improved Elevated Terminal
The 1914 patent “Apparatus for Transmitting Electrical Energy” refers to an improved elevated or free terminal.

Referring to the accompanying drawing, the figure is a view in elevation and part section of an improved free terminal and circuit of large surface with supporting structure and generating apparatus. . . . A part of the improvements which form the subject of this specification, the transmitting circuit, in its general features, is identical with that described and claimed in my original Patents Nos. 645,576 and 649,621. . . . [Dr. Nikola Tesla Complete Patents, p. 436]

Tesla’s work was directed towards the development of a system that combined wireless telecommunications and electrical power transmission, the communications component being Tesla’s initial goal. While electrical power transmission was viewed as being of greater importance, the attempt at its large-scale implementation would have taken place after the feasibility of the basic concept had been established.

The currents are proportionate to the potentials which are developed under otherwise equal conditions. If you have an antenna of a certain capacity charged to 100,000 volts, you will get a certain current; charged to 200,000 volts, twice the current. When I spoke of these enormous potentials, I was describing an industrial plant on a large scale because that was the most important application of these principles [the wireless transmission of electrical power], but I have also pointed out in my patents that the same principles can be applied to telegraphy and other purposes. That is simply a question of how much power you want to transmit. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 145]

When the system as configured for telecommunications purposes only, the potential of each elevated terminal might be relatively low. The energy flow between the elevated terminals is by
means of electrostatic induction.  *What if the distance between facilities is greater than one wavelength?*

For high power energy transmission by true electrical conduction, a very high potential on the elevated terminal is needed in order to break down the insulating stratum around and above each plant. As the potential is increased a point will eventually be reached at which charge on the terminal will 'break out' and form what Tesla called "streamers." Once this fault situation occurs, the potential drops and the system goes out of tune.

In this experiment, the voltage might have been something like 7 or 8 million volts, but I want to tell you, though, that I am referring to the maximum potential. The moment you get these enormous streamers the potential drops. I mean that was the breaking potential. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 112]

The maximum potential can be increased by the prevention of streamers. The 1914 patent shows an improved terminal that achieved this by modifying the terminal’s smooth surface with closely spaced hemispherical attachments.

A further improved terminal wasn’t available until the mid 1930s, at which time the following announcement appeared, “Tesla Prepares to Send Power Without Wires, Inventor, 80, Announces Solution of Problem He Worked on for 35 Years. Earth Will Carry Current. 100-Million-Volt Plant to be Build in Foreign Land,” (N. Y. Herald Tribune, July 27, 1936). It was the vacuum tube studded elevated terminal, disclosed in “New Art of Projecting Concentrated Non-Dispersive Energy Through Natural Media,” that freed him to make this statement.

Tesla’s improved terminal, circa 1936, consists of 1) a spherical frame, 2) an insulating bulb with an electrode of thin sheet metal suitably rounded and a metallic socket, exhausted to the highest vacuum obtainable, attached with 3) a nut fastener. [Nikola Tesla’s Teleforce and Telegeodynamics Proposals, p. 22]
The elevated terminal is involved in the launching of a plasma wave, a “disturbance of a plasma away from equilibrium, involving oscillations of the plasma's constituent particles and/or the electromagnetic field.” Propagation of the ion acoustic wave in plasma conforms with Tesla's description of “the universal medium...a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. (See THE GENERATION OF PLASMA WAVES AT THE EARTH’S SURFACE... ) (This is not to say that plasma is a requirement for the propagation of radio waves.) The high-power pulsed magnetic field produced by the helical-resonator transmitting element may also be involved in the conduction process.

Keeping in mind that plasma is an electrical conductor with finite resistivity, when attempting to simulate the World System, the mathematical model must incorporate a value for the effective resistance between the two elevated terminals as well as earth resistance and that of the ground connections.

The Connection to Earth

In 1916 Tesla described the underground portion of the Wardenclyffe tower in this way,

In this system that I have invented it is necessary for the machine to get a grip of the earth, otherwise it cannot shake the earth. It has to have a grip on the earth so that the whole of this globe can quiver, and to do that it is necessary to carry out a very expensive construction. I had in fact invented special machines.... There was a big shaft about ten by twelve feet goes down about one hundred and twenty feet and this was first covered with timber and the inside with steel and in the center of this there was a winding stairs going down and in the center of the stairs there was a big shaft again through which the current was to pass.... And then the real expensive work was to connect that central part with the earth, and there I had special machines rigged up which would push the iron pipe, one length after another, and I pushed these iron pipes, I think sixteen of them, three hundred feet, and then the current through these pipes takes hold of the earth. Now that was a very expensive part of the work, but it does not show on the tower, but it belongs to the tower. [Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power, p. 203]

Tesla System Receivers

Regarding the potential at the receiver's elevated terminal it is related to the potential at the transmitter's elevated terminal. As we are speaking of electrical conduction, I^R losses should be applicable in this case. The resistance is that of the intervening plasma between the two elevated terminals and of the earth between the two ground terminals. There is also a voltage divider in that some of the current associated with the elevated terminal passes to ground and back to the transmitter's ground terminal. This current, "circulates locally and is useless except that it adds to the momentum." [*The True Wireless* Electrical Experimenter, May 1919]

[Switching receiver patent description, charge accumulating capacitor.]

The Wavemeter

This consists of a grounded helical resonator with a widely adjustable elevated terminal and no local oscillator. It may have a small adjustable ferrite core. Incorporates an e-field probe detector with a high impedance amplifier or a few secondary turns with a low impedance amplifier. May incorporate active antenna circuitry (see Regeneration Revisited and John F. Sutton's U.S. Patent No. 5,296,866, Active antenna (March 22, 1994). [Abstract: An antenna, which may be a search coil, connected to an active circuit which provides negative impedances, each of which is of the order of magnitude of the positive impedances which characterize this active antenna. In one embodiment, one coil terminal is connected to an amplifier which drives a voltage-controlled current source that, in turn, drives a
feedback coil which is coupled to the original search coil. In another embodiment that additionally exhibits an advantageous signal-to-noise characteristic, both terminals of the search coil are connected to a differential amplifier that, in turn, provides the control voltage for a current source, which, as in the first embodiment, drives the feedback winding. The feedback coil is wound to provide positive feedback by additive superposition of both coil fields. The positive feedback provided by the feedback current lowers the antenna impedance which, in turn, increases the effective area of the antenna. This circuit configuration incorporates a differentiation inherent in the fundamental characteristic of a coil, which is sensitive to the rate-of-change of the magnetic field. The outstanding stability of this active antenna may be attributed to the inherent accuracy of this differentiation performed by the antenna coil, to the particular circuit configurations and to the particular form of feedback employed.

**The Dedicated or Domestic Receiver**

A grounded resonator with an adjustable elevated terminal plus a low-power local oscillator. Uses an e-field probe detector, or a secondary winding for drawing off small amounts of power.

**The Electrical Power Distribution Plant Substation**

A grounded magnifying transmitter perhaps larger than the Wardenclyffe prototype with fewer resonators, a fixed elevated terminal plus a medium-to-high-power local oscillator. Is linked to wired power distribution grid.

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**The Evolution of Tesla's Air-Ground System for Wireless Energy Transmission**

The air-ground system evolved from Tesla's one-wire method of energy transmission over a circuit that was not closed "in the ordinary acceptance of the term." While there is no physically solid second conductor connected back to the generator, the capacitor plates at both ends of the "one-wire" circuit couple to its counterpart or opposite member directly or through ground, depending upon the distance between the two terminals, thus constituting the return circuit.

![Fig. 184](image)

This, as well as the description "air-ground method" implies that the system depends upon the existence of a connection between the elevated terminals. Additional support to this assertion is found in the Electrical Transformer patent covering the Tesla coil, which describes electrical power transmission through a single wire with ground for return.
Tesla's 1897 patent drawing showing the transmission of electrical energy through one wire with ground for return.

Also, the apparatus used in the 1898 Patent Office demonstration at the Houston St. lab involved the transmission of electrical energy in industrial amounts through a rarified medium with ground for return.

Tesla's diagram representing the arrangement of apparatus as demonstrated to U.S. patent examiner G.D. Seeley in the Houston Street laboratory. This showed the transmission of electrical energy through a rarefied atmosphere with ground for return.
My experiments . . . in Colorado showed that at a height of 1 mile it is plenty enough rarefied to break down under the stress and conduct the current to the distant points. . . . My patent says that I break down the atmosphere "at or near" the terminal. If my conducting atmosphere is 2 or 3 miles above the plant, I consider this very near the terminal as compared to the distance of my receiving terminal, which may be across the Pacific. . . . I have constructed and patented a form of apparatus which, with a moderate elevation of a few hundred feet, can break the air stratum down. You will then see something like an aurora borealis across the sky, and the energy will go to the distant place. . . . An apparatus which permits displacing a certain quantity of electricity in the terminal—we shall say so many units—will produce an electric potential at a distance of 5 miles, and the fall of electric potential per centimeter will be equal to the quantity of electricity divided by the square of the distance. . . . Now, I have satisfied myself that I can construct plants in which I may produce, per kilometer of the atmosphere, electric differences of potential of something like 50,000 or 60,000 volts, and at 50,000 or 60,000 volts that atmosphere must break down and will become conductive. [NTAC]

Furthermore, Tesla made the following statement regarding his theory and technique of energy transmission.

The earth is 4,000 miles radius. Around this conducting earth is an atmosphere. The earth is a conductor; the atmosphere above is a conductor, only there is a little stratum between the conducting atmosphere and the conducting earth which is insulating. . . . Now, you realize right away that if you set up differences of potential at one point, say, you will create in the media corresponding fluctuations of potential. But, since the distance from the earth's surface to the conducting atmosphere is minute, as compared with the distance of the receiver at 4,000 miles, say, you can readily see that the energy cannot travel along this curve and get there, but will be immediately transformed into conduction currents, and these currents will travel like currents over a wire with a return. The energy will be recovered in the circuit, not by a beam that passes along
this curve and is reflected and absorbed, . . . but it will travel by conduction and will be recovered in this way. [NTAC]

Tesla’s diagram explanatory of the transmission of electrical energy by the ground air method. This was first put before Lord Kelvin in the Houston Street laboratory in September 1897.

It should be noted that in describing the “atmosphere above” as being conducting he roughly predicted the existence of the ionosphere and the earth-ionosphere cavity.
PIONEER RADIO ENGINEER GIVES VIEWS ON POWER

by Nikola Tesla

New York Herald Tribune, September 11, 1932

Tesla Says Wireless Waves Are Not Electromagnetic, But Sound In Nature
Holds Space Not Curved—Predicts Power Transmission to Other Planets

by Nikola Tesla

The assumption of the Maxwellian ether was thought necessary to explain the propagation of light by transverse vibrations, which can only occur in a solid. So fascinating was this theory that even at present it has many supporters, despite the manifest impossibility of a medium, perfectly mobile and tenuous to a degree inconceivable, and yet extremely rigid, like steel. As a result some illusionary ideas have been formed and various phenomena erroneously interpreted. The so-called Hertz waves are still considered a reality proving that light is electrical in its nature, and also that the ether is capable of transmitting transverse vibrations of frequencies however low. This view has become untenable since I showed that the universal medium is a gaseous body in which only longitudinal pulses can be propagated, involving alternating compressions and expansions similar to those produced by sound waves in the air. Thus, a wireless transmitter does not emit Hertz waves which are a myth, but sound waves in the ether, behaving in every respect like those in the air, except that, owing to the great elastic force and extremely small density of the medium, their speed is that of light.

Suggested Short Waves Early.

Since waves of this kind are all the more penetrating, the shorter they are, I have urged the experts engaged in the commercial application of the wireless art to employ very short waves, but for a long time my suggestions were not heeded. Eventually, though, this was done, and gradually the wavelengths were reduced to but a few meters. Invariably it was found that these waves, just as those in the air, follow the curvature of the earth and bend around obstacles, a peculiarity exhibited to a much lesser degree by transverse vibrations in a solid. Recently, however, ultrashort waves have been experimented with and the fact that they also have the same property was hailed as a great discovery, offering the stupendous promise to make wireless transmission infinitely simpler and cheaper.

It is of interest to know what wireless experts have expected, knowing that waves a few meters long are transmitted clear to the antipodes. Is there any reason that they would behave radically different when their length is reduced to about half of one meter?

Waves Go Around World.

As the general knowledge of this subject seems very limited, I may state, that even waves only one or two millimeters long, which I produced thirty-three years ago, provided that they carry sufficient energy, can be transmitted around the globe. This is not so much due to refraction and reflection as to the properties of a gaseous medium and certain peculiar action, which I shall explain some time in the future. At present it may be sufficient to call attention to an important fact in this connection, namely, that this bending of the beam projected from reflector does not affect in the least its behavior in other respects. As regards deflection in a horizontal plane, it acts just as though it were straight. To be explicit the horizontal deviations are comparatively slight. In a proposed ultrashort wave transmission, the vertical bending, far from being an advantage, is a serious drawback, as it increased greatly the liability of disturbances by obstacles at the earth's surface. The downward deflection always occurs, irrespective of wavelength, and also if the beam is thrown upward at an angle to the horizontal, and this tendency is, according to my finding, all the more pronounced the bigger the planet. On a body as large as the sun, it would be impossible to project a disturbance of this kind to any considerable distance except along the surface.
It might be inferred that I am alluding to the curvature of space supposed to exist according to the teachings of relativity, but nothing could be further from my mind. I hold that space cannot be curved, for the simple reason that it can have no properties. It might as well be said that God has properties. He has not, but only attributes and these are of our own making. Of properties we can only speak when dealing with matter filling the space. To say that in the presence of large bodies space becomes curved, is equivalent to stating that something can act upon nothing. I, for one, refuse to subscribe to such a view.

Need Radio Channels.

The chief object of employing very short waves is to provide an increased number of channels required to satisfy the ever-growing demand for wireless appliances. But this is only because the transmitting and receiving apparatus, as generally employed, is ill-conceived and not well adapted for selection. The transmitter generates several systems of waves, all of which, except one, are useless. As a consequence, only an infinitesimal amount of energy reaches the receiver and dependence is placed on extreme amplification, which can be easily affected by the use of the so-called three-electrode tubes. This invention has been credited to others, but as a matter of fact, it was brought out by me in 1892, the principle being described and illustrated in my lecture before the Franklin Institute and National Electric Light Association. In my original device I put around the incandescent filament a conducting member, which I called a "sieve." This device is connected to a wire leading outside of the bulb and serves to modify the stream of particles projected from the filament according to the charge imparted to it. In this manner a new kind of detector, rectifier and amplifier was provided. Many forms of tubes on this principle were constructed by me and various interesting effects obtained by their means shown to visitors in my laboratory from 1893 to 1899, when I undertook the erection of an experimental world-system wireless plant at Colorado Springs.

During the last thirty-two years these tubes have been made veritable marvels of mechanical perfection, but while helpful in many ways they have drawn the experts away from the simpler and much superior arrangement, which I attempted to introduce in 1901. My plans involved the use of a highly effective and efficient transmitter conveying to any receiver at whatever distance, a relatively large amount of energy. The receiver is itself a device of elementary simplicity partaking of the characteristics of the ear, except that it is immensely more sensitive. In such a system resonant amplification is the only one necessary and the selectivity is so great that any desired number of separate channels can be provided without going to waves shorter than a few meters.

For this reason, and because of other shortcomings, I do not attach much importance to the employment of waves, which are now being experimented with. Besides, I am contemplating the practical use of another principle, which I have discovered and which is almost unlimited in the number of channels and in the energy three-electrode tubes. This invention has been credited to others, but as a matter of fact, it was brought out by me in 1892, the principle being transmitted. It should enable us to obtain many important results heretofore considered impossible. With the knowledge of the facts before me, I do not think it hazardous to predict that we will be enabled to illuminate the whole sky at night and that eventually we will flash power in virtually unlimited amounts to planets. It would not surprise me at all if an experiment to transmit thousands of horsepower to the moon by this new method were made in a few years from now.
Faster Than Light!

By HUGO GERNSBACK

It may come as a shock, to most students of science, to learn that there are still in the world some scientists who believe that there are speeds greater than that of light.

Since the advent of Einstein, most scientists and physicists have taken it for granted that speeds greater than 186,280 miles per second are impossible in the universe. Indeed, one of the principal tenets of the relativity theory is that the mass of a body increases with its speed, and would become infinite at the velocity of light. Hence, a greater velocity is impossible.

Among those who deny that this is true, there is Nikola Tesla, well known for his hundreds of important inventions. The induction motor and the system of distributing alternating current are but a few of his great contributions to modern science. In 1899, he made his historic experiments in Colorado; where he manufactured, for the first time, artificial lightning bolts 100 feet long, and where he was able, by means of high-frequency currents, to light electric lamps at a distance of three miles without the use of any wires whatever.

Talking to me about these experiments recently, Dr. Tesla revealed that he had made a number of surprising discoveries in the high-frequency electric field and that, in the course of these experiments, he had become convinced that he propagated frequencies at speeds higher than the speed of light.

In his patent No. 787,412, filed May 16, 1900, Tesla showed that the current of his transmitter passed over the earth's surface with a speed of 290,800 miles per second, while radio waves proceed with the velocity of light. Tesla holds, however, that our present "radio" waves are not true Hertzian waves, but really sound waves.

He informs me, further, that he knows of speeds several times greater than that of light, and that he has designed apparatus with which he expects to project so-called electrons with a speed equal to twice that of light.

Coming from so eminent a source, the statement should be given due consideration. After all, abstract mathematics is one thing, and actual experimentation is another. Not so many years ago, one of the world's greatest scientists of the time proved mathematically that it is impossible to fly a heavier-than-air machine. Yet we are flying plenty of airplanes today.

Tesla contradicts a part of the relativity theory emphatically, holding that mass is unalterable; otherwise, energy could be produced from nothing, since the kinetic energy acquired in the fall of a body would be greater than that necessary to lift it at a small velocity.

It is within the bounds of possibility that Einstein's mathematics of speeds greater than light may be wrong. Tesla has been right many times during the past, and he may be proven right in the future. In any event, the statement that there are speeds faster than light is a tremendous one, and opens up entirely new vistas to science.

While it is believed by many scientists, today, that the force of gravitation is merely another manifestation of electromagnetic waves, there have, as yet, been no proofs of this. There are, of course, many obscure things about gravitation that we have not, as yet, fathomed.

At one time, it was believed by many scientists that the speed of gravitation is instantaneous throughout the universe. This is simply another way of putting it that there are speeds greater than light.

Yet, from a strictly scientific viewpoint, no one today has any idea how fast gravitational waves—always providing that the force is in waves—travel. If the moon, for instance, were to explode at a given moment, how long would it be before the gravitational disturbance would be felt on earth? Would the gravitational impulse or waves travel at the speed of light—that is, 186,000 miles per second—or would the effect be instantaneous? We do not know.

The entire subject will no doubt arouse a tremendous interest in scientific circles. It is hoped that other scientists will be encouraged to investigate Dr. Tesla's far-reaching assertions; either to definitely prove or to disprove them.
Rare notes from Tesla on Wardenclyffe

LELAND ANDERSON HAS KINDLY PROVIDED COPIES OF RARE DOCUMENTS FROM THE TESLA MUSEUM IN BELGRADE. THE PAPERS REPRODUCED IN THIS REPORT SUPPLY INFORMATION ABOUT THE WARDENCLYFFE TOWER, AND SHOW THAT THE DESIGN PROCESS WASN'T AS AUTOMATIC AS LEGEND LEADS US TO BELIEVE.

Tesla's tower at Wardenclyffe is perhaps as enigmatic as the prodigal genius was himself. (Figs. 1-3 show in part the conceptual evolution of the tower.) While Tesla aficionados have scraped the archives and haggled with politicos to obtain even the minutest revelations on how this device might have actually been capable of transmitting energy worldwide, nobody seems to know how this was to be effected. In what follows, the contents of some practically-uncirculated papers, that Leland Anderson managed to obtain, are reproduced in full.

The first note, written on Waldorf-Astoria letterhead, discloses Tesla's reasoning behind some of the dimensional specifications required in an early design for the tower which he claimed would be capable of transmitting electricity worldwide by means of earth resonance. The letters reprinted here were all written in 1901. Actual construction of the tower did not start until December 12, 1901.

New York May 29, 1901
from old note
In annexed sketch [See Fig. 4.] a terminal C' in form of a roof is supported on conducting supports L_L. Terminal C is adjustable and in contact with structure of roof, or terminal C'. A resonating system C_LSE discharges with C, and produces oscillations in system C_LFE. This arrangement obviates necessity to support roof or terminal C on insulated supports.

Now in a sketch or scheme the difficulty will be probably to get the oscillations of the free system C_LFE, slow enough to be very effective in transmission through earth as in my system. The length of conductors in the free system should be λ/4, and the length of the discharging current should be 3/4 λ or n/4 λ eventually, n being uneven number.

Suppose, to get an idea, we take C' = 10,000 cm. This is realizable. Then we have

$$\frac{2\pi}{10^2} \sqrt{\frac{L \times 10,000}{9 \times 10^5}}$$

the period of the system. We should have vibration not much quicker than 100,000 and to satisfy this L would have to be:

$$\frac{1}{100,000} = \frac{2\pi}{10^3} \frac{L}{\sqrt{90}}$$

$$L = 9 \times 10^4 = 225,000 \text{ cm.}$$

Calculated it would appear that the supports L would have to be about 600 feet. The arrangement would be OK with quick oscillation. The self-induction of a straight conductor is $$L' = 2\pi(\text{log}(2\pi r) - 0.75)$$. Now, take r = 300 ft = 9000 cm. If we want to use iron pipes 4" diam. r = 5 cm. Then 2πr = 3600 and from this I find L' = 134,000 cm. Again taking the length 600 ft we would get inductance probably 268,000 cm. To get lower frequencies, evidently in above scheme self-induction must be increased.

P.S. The charging and discharge current may even be of different period and both vibrations used to excite receiver.
RARE NOTES FROM TESLA ON WARDENCLYFFE

The person who proofread the decipherer's notes found fault with Tesla's analysis, stating that in order to limit the induction to 225,000 cm, the tower would need to be nearly three times taller than Tesla anticipated, or 1,404 feet high.

As it was, the Wardenclyffe Tower project was very large, and involved numerous construction crews. The following note was sent to Margaret Cheney, while she was writing Tesla's biography.

Wardenclyffe Project
Reference has been made by O'Neill and contemporary newspaper accounts of the large crew that Tesla had working for him at Wardenclyffe. Instead of just referring to the "large crew" as such, it might be a good idea to sprinkle in a few names of Tesla's direct assistants. They were:
Willie Eppersteiner
Hartmann
Johnnison
Lindeke
Meyer
Alfred Peters
Seibel
Mr. Uhlman (815 N. 12th St., St. Joseph, MO)
Wagner (Tesla's glass blower)

LETTERS
The next three letters illustrate, to a small degree, the breadth of the concerns Tesla had while overseeing the building of his tower. The first two are written to the architect, Stanford White; the third is to the company that was to furnish the building's boilers.

New York, Aug. 28th, 1901
46 & 48 East Houston Str.

Mr. Stanford White
160 Fifth Ave.
New York City

My Dear Stanford:
I have seen the American Bridge people today to ascertain whether they will be able to construct the cupola of my building without much delay. As this item will consume the longest time, it is necessary to take all the preliminary steps so that the work may begin just as soon as you have passed upon the plans. I believe that the American Bridge Company is the best concern to deal with in this matter, but I beg you not to pay any attention to my suggestion, if you think otherwise.

The Bethlehem Steel Company will furnish me the sheets, but I cannot give the order until we have agreed upon all details.

With kind regards,
Yours very sincerely,
N. Tesla

Fig. 1
Fig. 2
Fig. 3
Fig. 4
New York, Aug. 30th, 1901
46 & 48 East Houston St.

Mr. Stanford White
160 Fifth Ave.
New York City

My Dear Stanford:
Many thanks for your suggestions. I am writing to Mr. Powell today. Perhaps he will be able to clear the land altogether.

I want you to understand that I went to the American Bridge Company simply because of my anxiety to have the work pushed through as fast as practicable. I am only too glad to follow your advice and beg you to consider yourself absolutely free in your choice and arrangements regarding this work.

Yours very sincerely,
N. Tesla

New York, Sep. 12th, 1901
46 & 48 East Houston St.

Babcock & Wilcox Co.
85 Liberty Street
New York City

Gentlemen:
Under enclosure I forward sketch showing your two boilers as they will be placed in my building and their position relative to and exact distance from the chimney. The scale is ½ inch to a foot.

You will greatly oblige me by furnishing the drawings of the flues leading to the chimney and the position of the breech, as the builder cannot proceed without this information.

Yours very truly,
Encl.

Anyone familiar with the Wardenclyffe Tower knows it to have been a colossal structure. Yet, few realize that it was supposed to have been even larger. Although the exact figures are not revealed, Tesla must have drastically underestimated the cost of building his structure as is evidenced by the following response to White.
New York, Sep. 13th, 1901
46 & 48 East Houston Street

Mr. Stanford White
160 Fifth Ave.
New York City

My Dear Stanford:
I have not been half as dumfounded by the news of the shooting of the President as I have by the estimates submitted to you, which, together with your kind letter of yesterday, I received last night.

One thing is certain: We cannot build that tower as outlined.

I cannot tell you how sorry I am, for my calculations show, that with such a structure I could reach across the Pacific. Since last night, I have thought carefully over the matter and have come to the conclusion that the best plan will be to fall back on an older design which I have made, involving the use of two and possibly three towers, but much smaller. We would keep the design of the tower the same and would only reduce the dimensions. It will probably be best to adopt a design with two towers and a low central part for the machinery. I shall make some calculations today and will see how far I can reduce the height without impairing materially the efficiency of the apparatus, and will communicate with you as soon as practicable.

Thanking you heartily for your friendly interest and efforts on my behalf, I remain,

Yours very sincerely,

N. Tesla
RARE NOTES FROM TESLA ON WARDENCLYFFE

Sept. 18, 1901
Following results may be confidently expected with smaller tower 200 feet and terminal roof of cheap construction as last designed. The roof will comprise a single platform with spherical bodies of large curvature on rim.

The construction of latter will be given in detail. The platform 20 meters diameter, 15 round surfaces on top and 15 on the bottom as shown in sketch below.

It is difficult to estimate in advance the capacity of the structure with precision, but an approximate idea may be obtained. The spherical bodies will be each of a capacity of 200 cm. This would give 30 \times 200 = 6000 \text{ cm without taking elevation into consideration. But owing to proximity capacity will be much smaller. Estimates place the minimum value at or less than 1000 \text{ cm (elevation not considered).}}

This means, say, that of each spherical body only 1/6 of surface is fully active.

Now, surface of one spherical body will be \( \pi \times 400^2 \). Calling \( \sigma \) density, we would have on 1/6 of surface

\[
\frac{\pi \times 400^2 \sigma}{6 \times 3 \times 10^6} = \text{Coul of electricity.}
\]

We can safely make \( \sigma = 10 \) minimum. This would give on the whole structure

\[
\frac{\pi \times 400^2 \times 10 \times 30}{6 \times 3 \times 10^6} = \text{roughly at least 8/10^3 Coulombs. Now, if we put capacity as 1000 \text{ cm we would have}}
\]

\[
\frac{8}{10^3} = \frac{1000}{9 \times 10^1} \cdot V
\]

and

\[
V = \frac{9 \times 8 \times 10^1}{10^6} = 7,200,000 \text{ volts.}
\]

This estimate is surely small and we may take safely 10,000,000 volts for 1000 cm capacity.

Considering simply earth as ball and leaving out short waves, we have since \( eP = C \cdot r \), \( V = P = 10^6 \text{ volts; } e = 1000 \text{ cm.} \)

\( C = \text{capacity of earth } = 636 \times 9 \times 10^1 \)

\[
\frac{1000}{9 \times 10^1} \times P = \frac{636 \times 9 \times 10^5}{9 \times 10^1} \times P,
\]

\( P = \text{simply 16 volts. This means variation of } 2P = 32 \text{ volts all over globe.} \)

Decipherer's Notes
Again, the decipherer's proofreader took issue. Using 636 \times 10^6 \text{ cm as the value for earth's capacitance, he arrived at the conclusion that } P \text{ should equal } 11 \text{ and not } 16 \text{ volts.}

By October, Tesla was quite pleased with his projections for the new tower's output. The decipherer's proofreader had no objections, either.

Oct. 15, 1901
Consideration relative to rate of energy delivery at any point of globe with Long Island apparatus.

Assume that a grounded secondary is employed excited by a primary through which condenser discharges and let both the circuits be in perfect tune so that the secondary system vibrates the same rate whether the primary be closed or open. The form of wave is then as illustrated in diagram. [See Fig 9.] At a primary begins to excite, at b somewhere in the middle of wave train primary is opened and at c vibrations in secondary cease. In this form of electrical movement the current and emf are in phase, hence the power is always given by the product of these quantities during each half wave, but it must be remembered that the energy is passing from static to kinetic form and consequently the actual power is only that supplied by primary. The secondary circuit increases the amplitude only. But in many cases what is desired is simply a maximum rate. So for instance in telegraphy when a device like a minute spark gap is employed in connection with a tuned circuit. Let us then see what can be expected as reasonable during one swing.
In previous examples, \( E_{\text{max}} = 9/8 \times 10^4 \) volt.

\[
\text{Current (average)} = \frac{4 \pi x 10^3 M}{2 \times 10^3} = 2000 \text{ amp}
\]

\( \omega = 4 \pi x 10^3 \) M = \( 2 \times 10^3 \). Hence for largest swing rate of power will be 

\[
E_{\text{max}} \times J_{\text{max}} = \frac{9}{8} \times 10^4 \times \pi x 2 \times 2000 = 35 \times 10^4
\]

WG. Now on equatorial belt we shall have:

Circumference of belt about \( 4 \times 10^3 \) cm. Suppose a strip of ground \( 1000 \) cm wide \( \pi / 2 \) = \( 93/200 \) miles is utilized. The current through the strip will be

\[
\frac{1000}{4 \times 10^3} \times \frac{\pi}{2} \times 2000 = I_{\text{max}} = \frac{\pi}{4 \times 10^3}
\]

Energy in strip considering superficial propagation will be similarly

\[
W_{\text{max}} = \frac{1000}{4 \times 10^3} \times 35 \times 10^6 = 875 \text{ watts.}
\]

\( e_{\text{max}} = 875 \times 4 \times 10^6 \pi = 11 \times 10^9 \) volt. Assuming magnifying factor in receiving circuit = 100 we may get with a tuned circuit \( e_r = 11 \times 10^7 \) volt, \( f_r = \pi / 40 \) amp and \( W_r = 11 \pi \times 10^7 / 40 = 86 \times 10^5 \) watts. Perfectly wonderful!
For Many Years Electrical Engineers Have Endeavored to Devise Some Means Whereby It Would Become Possible to Utilize the Free Electrical Energy Ever Present in the Atmosphere, But They Were Not Successful, as Every Now and Then an Extra Heavy Surge of Static Current Would Rush Down the Elevated Conductor and Endanger the Lives of the Experimenters, or Else Destroy the Apparatus Connected With It. A German Engineer Has, However, Devised the Somewhat Elaborate Scheme Here Shown in Brief, and He Has Succeeded, at Least so His Report States, in Safely Extracting Several Kilowatts of Electrical Power from the Atmosphere With Metallic Surfaced Balloons, Elevated to a Height of Only 1,000 Feet.

We have previously treated of the extraction of electrical energy from the atmosphere. The difference of electric potential in different parts of the atmosphere, and the difference between the upper air and earth make it a tempting proposition to obtain power from atmospheric electricity. The power would take the form of high potential difference with a discharge almost of a static nature. It has long appeared rather doubtful to conservative engineers, if such a source of power should really be available. Yet when we see the lightning flash, it certainly suggests very high power, even though the total of its
energy may be small, on account of the small duration of the discharge. It is not to the thunder storm that we look for getting power from the atmosphere, as the subject is now being seriously investigated. A German scientist, Hermann Plauson, has published a very elaborate work on this subject, and has investigated the use of kites, balloons and towers, for the utilization of the high potentials existing in the air at different altitudes, and has studied out the construction of motors to be operated by the peculiar type of discharge which will be obtained, if the projects are successfully carried out.

We will first speak of the methods used for collecting electricity from the upper air. The author cites several German patents. One of them shows the use of a kite balloon. The balloon is shown floating in the air, kite fashion, and from it hangs a great net or aerial for the collection of electricity. The conductor from the aerial leads to the ground station; quite an elaborate description is given of the net-work which the patentee proposes to have covered with needle points. A windlass takes in or pays out cable for the balloon, and the patentee claims that by sending the apparatus to a height of about one mile he will have 225,000 volts to draw upon. He then speaks of a battery of 20,000 cells in series, which will use up to 40,000 to 50,000 volts in the charging. This certainly provides for a reasonable large fall of potential.

But our author discards this idea and first suggests something more permanent. He proposes the erection of towers to be in the neighborhood of 1,000 feet high, or about the height of the Eiffel Tower. At the summit he has his collecting aerial. The appliance consists of a number of copper tubes; within each one he proposes to burn gas lamps, whose products of combustion will reach the aerial, a collecting net-work covering the tops of the tubes. One of his apprehensions is that if rain should wet his connections trouble might ensue, so he proposes a protection at the top in the shape of a great bell-like shield, resembling in his terms “a Siamese pagoda”. He also compares the form of the protection to that of a great petticoat insulator. Another of his difficulties is that he must have his tower insulated from the earth. He, therefore describes a complicated foundation for his structure. He proposes first to pour in at the bottom of the excavation a foundation of simple concrete. On this he places a layer of asphalt, and then a layer of cast glass, three to ten feet thick, and then comes a reinforced concrete foundation, to which the metallic foot of the tower is to be anchored. This foundation must rise at least seven feet above the ground level, and is to be boarded in on all sides to protect it from moisture. The author’s idea is to erect a number of these towers connected by a horizontal cable, to which the aerials for collection of potentials are secured.

The author strongly advocates balloons as collectors of the electric power of the air. These he depicts covered with spots. These spots indicate areas to be variously coated and prepared to collect potential from the atmosphere.

In the first place he describes the balloon as made of thin metallic leaf supported by internal ribs. Steel wires silver-plated, copper-plated, or aluminum-coated, run from the balloon to the pendant or junction ring. To this ring the
tether cable is attached and runs to an insulated windlass on the surface of the earth. The balloon is to rise to an altitude varying from 300 feet to three miles.

The coating of the spots is to be of the thinnest amalgam, of mercury and gold, or zinc, or even polonium, perhaps only 1/2500 inch thick. All over the upper face of the balloon are numberless metal points. To prepare the needle-like wires, they are collected into bundles and are treated electrolytically in a bath, so as to be dissolved in part. This gives a sharp point and roughened surface, all adapted for collecting the electric energy. The points may be of copper, steel, or some hard metallic alloy. After this corrosion. As it may be termed, the wires are plated with gold or other of the so-called noble metals. It is advised that polonium or radium salts be added to the plating bath.

Dr Plauson devotes many pages of his book to describing his motor. This is a rotary motor including a stator and rotor and its peculiarity is that it contains no coils, develops no electromagnetic field properly speaking, but works by static excitation. One typical arrangement is shown in our illustration. The stator plates and rotor plates are concentric with each other, representing segments of cylinders. The alternation of negative and positive charged plates produces the rotation. In the connections there is included a safety spark gap to take care of dangerous potentials. Inductances and capacities are also used and indicated. It was found that the plates heated, owing to the Foucalt currents, and to overcome this, several methods of subdividing the stator and rotor plates, are described by the author.

The whole subject is quite captivating, and it really seems as if the utilization of the electricity of the air may be almost in sight. It would seem possible to carry out experiments in this direction by means of the Eiffel Tower, but of course, the trouble here is that the tower is grounded, and perfect insulation of the collecting surface is absolutely essential.

And now our author gives us some practical details. He says that on the Finland plains he carried out experiments with a balloon made of aluminum leaf with collecting needles of amalgamated zinc with a radium preparation as an ionizer. The surface of the balloon was sprinkled over with zinc amalgam. It was sent up to a height of 300 meters, early 1,000 feet, and was held by a copper-plated steel wire. A constant current of 1.8 amperes at an average of 400 volts potential difference was obtained. This gave nearly three-quarters of a kilowatt, or close to one horsepower. The collector of the balloon insulated from the earth showed a tension of 42,000 volts. By sending up a second balloon with an antenna to the same height at a distance of 100 meters from the first balloon, a current of over 3 amperes was obtained. Then by putting into the circuit a large condenser, whose capacity was equal to the surface capacity of both balloons, and of the antenna connections, the current rose to 6.8 amperes with about 500 volts mean tension. By the use of these two balloons, he eventually ran up the power to 3.4 kilowatts.
CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

Fig. 26.
CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY

Fig. 31.

Fig. 32.

Fig. 33.

Inventor
Hermann Plauson

By Knight...
UNIVERSITY PATENT OFFICE.

HERMANN PLAUSON, OF HAMBURG, GERMANY.

CONVERSION OF ATMOSPHERIC ELECTRIC ENERGY.

Application filed January 13, 1921, Serial No. 437,107.

To all whom it may concern:

Be it known that I, HERMANN PLAUSON, Estonian subject, residing in Hamburg, Germany, have invented certain new and useful Improvements in the Conversion of Atmospheric Electric Energy, of which the following is a specification.

Methods of obtaining atmospheric electricity by means of metallic nettings set with spikes which are held by means of ordinary or anchored kite balloons made of fabrics and filled with hydrogen, are in theory already known. Atmospheric electricity obtained in this way has been suggested to be used in the form of direct current for the charging of accumulators. This knowledge however is at present only theoretical as the conversion in practice has hitherto been a failure. No means are known of protecting the apparatus from destruction by lightning.

The balloons used for collecting the charge must also be made of very large size in order to be able to support the weight of the metallic netting and the heavy cable connections.

Instead of using heavy metallic netting as collectors attached to single air balloons of non-conducting materials which are liable to be torn and permeable to the gas, it is proposed to use metallic balloon collectors which have the following important advantages—

(a) The metallic cases are impenetrable to helium and hydrogen; they also represent large metallic weather-proof collecting surfaces.

(b) Radio active means and the like may be easily applied internally or externally; whereby the ionization is considerably increased and therewith also the quantity of atmospheric electricity capable of being collected.

(c) Such balloon collectors of light metal do not require to be of large size as they have to carry only their own moderate weight, and that of the conducting cable or wire.

(d) The entire system therefore offers little surface for the action of storm and wind and is resistant and stable.

(e) Each balloon can be easily raised and lowered by means of a winch so that all repairs, recharging and the like can be carried out without danger during the operation.

It is further proposed to use a collecting aerial network of several separate collectors spread out in the air above the earth, which collectors are interconnected by electrical conductors.

According to this invention charges of atmospheric electricity are not directly converted into mechanical energy, and this forms the main difference from previous inventions, but the static electricity which runs to earth through aerial conductors in the form of direct current of very high voltage and low current strength is converted into electro-dynamic energy in the form of high frequency vibrations. Many advantages are thereby obtained and all disadvantages avoided.

The very high voltage of static electricity of a low current strength can be converted by this invention to voltages more suitable for technical purposes and of greater current strength. By the use of closed oscillatory circuits it is possible to obtain electromagnetic waves of various amplitude and thereby to increase the degree of resonance of such current. Such resonance allows various values of inductance to be chosen whereby again the governing of the starting and stopping of machines driven thereby by simply tuning the resonance between coils of the machine and the transformer circuit forming the resonance can easily be obtained. Further, such currents have the property of being directly available for various uses, even without employing them for driving motors, of which there may be particularly mentioned, lighting, production of heat and use in electro-chemistry.

Further, with such currents a series of apparatus may be fed without direct current supply through conductors and also the electro-magnetic high frequency currents may be converted by means of special motors adapted for electro-magnetic oscillations into mechanical energy, or finally converted by special machines into alternating current of low frequency or even into direct current of high potential.

The invention is more particularly described with reference to the accompanying diagrams in which—

Figure 1 is an explanatory figure.
Figure 2 is a diagrammatic view of the simplest form.
Figure 3 shows a method of converting atmospheric electrical energy for use with motors.

Figure 4 is a diagram showing the use of protective means.

Figure 5 is a diagram of an arrangement for converting large current strengths.

Figure 6 is a diagram of an arrangement including controlling means.

Figure 7 shows means whereby the spark gap length can be adjusted.

Figure 8 shows a unipolar connection for the motor.

Figure 9 shows a weak coupled system suitable for use with small power motors.

Figures 10, 11 and 12 show modified arrangements.

Figure 13 shows a form of inductive coupling for the motor circuit.

Figure 14 is a modified form of Figure 13 with inductive coupling.

Figure 15 is an arrangement with non-inductive motor.

Figure 16 is an arrangement with coupling by condenser.

Figures 17, 18 and 19 are diagrams of further modifications.

Figure 20 shows a simple form in which the aerial network is combined with special collectors.

Figure 21 shows diagrammatically an arrangement suitable for collecting large quantities of energy.

Figure 22 is a modified arrangement having two rings of collectors.

Figure 23 shows the connections for three rings of collectors.

Figure 24 shows a collecting balloon and diagram of its connection of condenser batteries.

Figures 25 and 26 show modified collector balloon arrangements.

Figure 27 shows a second method of connecting condutor for the balloon aerials.

Figure 28 shows an auto-transformer method of connection.

Figure 29 shows the simplest form of construction with incandescent cathode.

Figure 30 shows a form with cigar shaped balloon.

Figure 31 is a modified arrangement.

Figure 32 shows a form with cathode and electrode enclosed in a vacuum chamber.

Figure 33 is a modified form of Figure 32.

Figure 34 shows an arc light collector.

Figure 35 shows such an arrangement for alternating current.

Figure 36 shows an incandescent collector with Nernst lamp.

Figure 37 shows a form with a gas flame.

Figure 1 illustrates a simple diagram for converting static electricity into dynamic energy of a high number of oscillations.

For the sake of clearness in the drawings an influence machine is assumed to be employed and not an aerial antenna. 13 and 14 are combs for collecting the static electricity of the influence machine. 7 and 8 are spark discharging electrodes, 6 and 5 condensers, 9 an inductive primary coil, 10 secondary coil, 11 and 12 ends of conductors of the secondary coil 10. When the disc of the static influence machine is rotated by mechanical means, the combs collect the electric charges one the positive and the other the negative, and charge the condensers 5 and 6 until such a high potential is formed across the spark gap 7—8, that the spark gap is jumped. As the spark gap 7—8 forms a closed circuit with condensers 6 and 5, and inductive resistance 9, as is well known, waves of high frequency electromagnetic oscillations will pass in this circuit.

The high frequency of the oscillations produced in the primary circuit induces waves of the same periodicity in the secondary circuit. Thus in the primary circuit electromagnetic oscillations are formed by the passage of the spark over the spark gap and these waves are maintained by fresh charges of static electricity.

By suitably selecting the ratio between the number of the coils in the primary and secondary circuits with regard to a correct application of the co-efficients of resonance (capacity, inductance, and resistance) the high voltage of the primary circuit may be suitably converted into low voltage and high current strength.

When the oscillatory discharges in the primary circuit becomes weaker or entirely cease, the condensers are charged again by the static electricity until the accumulated charge again breaks down the spark gap. All this is repeated as long as electricity is produced by the static machine by employing mechanical energy.

An elementary form of the invention is shown in Figure 2 in which two spark gaps in parallel are used one of which may be termed the working gap 7 in Figure 2, whilst the second serves as a safety device for excess voltage and consists of a larger number of spark gaps than the working section, which gaps are arranged in series and are bridged by very small capacities as is illustrated in $a_1$, $b_1$, $c_1$, Figure 2 which allow of uniform sparking in the safety section.

In Figure 2 A is the aerial antenna for collecting charges of atmospheric electricity. 13 is the earth connection of the second part of the spark gap. 5 and 6 are condensers; 9 a primary coil. Now when through the aerial A the positive atmospheric electricity seeks to combine with the negative charge to earth, this is prevented by (the air gap between) the spark gaps. The resistance of the spark gap 7 is, as shown in the drawings, lower than that of the other safety section which consists of three spark gaps connected in.
series, and consequently a three times greater air resistance is offered by the latter.

So long therefore, as the resistance of the spark gap 7 is not overloaded, so that the other spark gaps have an equal resistance with it the discharges take place only over spark gap 7. Should however the voltage be increased by any influences so that it might be dangerous for charging the condensers 5 and 6 or for the coil insulation 9 and 10 in consequence of break down, by a correct regulation of this spark gap the second spark gap can discharge free from inductive effects direct to earth without endangering the machine.

Without this second spark gap, arranged in parallel having a higher resistance than the working spark gap it is impossible to collect and render available large quantities of electrical energy.

The action of this closed oscillation circuit consisting of spark gap 7, two condensers 5 and 6, primary coil 9, and also secondary coil 10 is exactly the same as the one described in Figure 1 with the arrangement of the static induction machine with the only difference that here the second spark gap is provided. The electromagnetic high frequency alternating current obtained can be tapped off from the conductors 11 and 12 for lighting and heating purposes. Special kinds of motors adapted for working with these peculiar electrical charges may be connected at 14 and 15 which can work with static electricity charges or with high frequency oscillations.

In addition to the use of spark gaps in parallel a second measure of security is also necessary for taking off the current. This precaution consists according to this invention, in the introduction of and method of connecting certain protective electromagnetic or choking coils in the aerial circuit as shown by S in Figure 3.

A single electromagnet only having a core of the thinnest possible separate laminations is connected with the aerial.

In the case of high voltages in the aerial network or at places where there are frequent thunder storms, several such magnets may however be connected in series.

In the case of large units or plants several electromagnets can be employed in parallel or in series parallel.

The windings of these electromagnets may be simply connected in series with the aerials. In this case the winding preferably consists of several thin parallel wires, which make up together, the necessary section.

The winding may be made of primary and secondary windings in the form of a transformer. The primary winding will be then connected in series with the aerial network, and the secondary winding more or less short-circuited over a regulating resistance or an induction coil. In the latter case it is possible to regulate to a certain extent the effect of the choking coils. In the further description of the connecting and constructional diagrams the aerial electromagnetic choke coil is indicated by a simple ring S.

Figure 3 shows the simplest way of converting atmospheric electricity into electromagnetic wave energy by the use of special motors adapted for high oscillatory currents or static charges of electrical energy. Recent improvements in motors for working with static charges and motors working by resonance, that is to say, having groups of tuned electromagnetic cooperating circuits render this possible but such do not form part of the present invention.

A motor adapted to operate with static charges will for the sake of simplicity be diagrammatically indicated by two semicircles 1 and 2 and the rotor of the motor by a ring M. (Figure 3.) A is a vertical aerial or aerial network. S the safety choke or electromagnetic with coil O as may be seen is connected with the aerial A. Adjacent the electromagnet S the aerial conductor is divided into three circuits, the circuit 8 giving the safety spark gap, the circuit 7 with the working spark gap, and then a circuit including the stator terminal 1, the rotor and stator terminal 2 at which a connection is made to the earth wire. The two spark gaps are also connected metallically with the earth wire. The method of working these diagrams is as follows:

The positive atmospheric electric charge collected tends to combine with the negative electricity (or earth electricity) connected with the earth wire. It travels along the aerial A through the electromagnet S without being checked as it flows in the same direction as the direct current. Further, its progress is arrested by two spark gaps placed in the way and the stator condenser surfaces. The stator condenser surfaces are charged until the charge is greater than the resistance of the spark gap 7, whereupon a spark springs over the spark gap 7 and an oscillatory charge is obtained as by means of the motor M, stator surfaces 1 and 2, and spark gap 7, a closed oscillation circuit is obtained for producing the electromagnetic oscillations. The motor here forms the capacity and the necessary inductance and resistance, which, as is well known, are necessary for converting static electricity into electromagnetic wave energy.

The discharges formed are converted into mechanical energy in special motors and can not reach the aerial network by reason of the electromagnet or choke. If, however, when a spark springs over the spark gap 7 a greater quantity of atmospheric electricity tends to flow to earth, a counter voltage is
induced in the electromagnet, which is greater the more rapidly and strongly the flow of current direct to the earth is. By the formation of this opposing voltage a sufficiently high resistance is offered to the flow of atmospheric electricity direct to earth to prevent a short circuit with the earth.

The circuit containing spark gap $S$ having a different wave length which is not in resonance with the natural frequency of the motor, does not endanger the motor and serves as security against excess voltage, which, as practical experiments have shown, may still arise in certain cases, but can be conducted direct to earth through this spark gap.

In the diagram illustrated in Figure 4 the spark gap $S$ is shunted across condensers $E_5$ and $E_6$ from the motor $M$. This construction affords mainly a better insulation of the motor against excess voltage and a uniform excitation through the spark gap $S$.

In Figure 5 a diagram is illustrated for transforming large current strengths which may be employed direct without motors, for example, for lighting or heating purposes. The main difference is that here the spark gap consists of a star shaped disc $7$ which can rotate on its own axis and is rotated by a motor opposite similarly fitted electrodes $7^a$. When separate points of stars face one another, discharges take place, thus forming an oscillation circuit over condensers $E_5$ and $E_6$ and inductance $9$ for oscillatory discharges. It is evident that a motor may also be directly connected to the ends of the spiral $9$.

The construction of the diagram shown in Figure 6 permits of the oscillation circuit of the motor being connected with an induction coil. Here a regulating inductive resistance is introduced for counter-acting excess voltages in the motor. By cutting the separate coils $9$ (coupled inductively to the aerial) in or out the inductive action on the motor may be more or less increased or variable aerial action may be exercised on the oscillation circuit.

In Figure 7 the oscillation circuit is closed through the earth ($E$ and $E_1$). The spark gap $S$ may be prolonged or shortened by more or fewer spark gaps being successively connected by means of a contact arm $7^a$.

Diagram 8 shows a unipolar connection of the motor with the aerial network. Here two oscillation circuits are closed through the same motor. The first oscillation circuit passes from aerial $A$ through electromagnet $S$, point $a$, inductance $9^a$ to the earth condenser $E_6$ and further, over spark gap $S$ to the aerial condenser $E_5$ and back to $a$. The second oscillation circuit starts from the aerial condenser $E_5$ at the point $a^1$ over the inductance $9^b$ to the earth condenser $E_6$ at the point $a^2$ and through the condenser $6$ over the spark gap $S$ back to $a^1$. The motor itself is inserted between the two points of the spark gap $S$. From this arrangement slightly damped oscillation wave currents are produced.

In the diagram illustrated in Figure 9 a loosely coupled system of connections is illustrated which is assumed to be for small motors for measuring purposes. A indicates the aerial conductor, $S$ the electromagnet in the aerial conductor, $9$ the inductance, $S$ the spark gap, $5$ and $6$ condensers, $E$ the earth, $M$ the motor, and $1$ and $2$ stator connections of the motor. The motor is directly metallically connected with the oscillation circuit.

In Figure 10 a purely inductive coupling is employed for the motor circuit. The motor is connected with the secondary wire to $a$ as may be seen in Figure 11 in a somewhat modified diagram connection. The same applies to the diagram of Figure 12.

The diagrams hitherto described preferably allow of motors of small and medium strength to be operated. For large aggregates, however, they are too inconvenient as the construction of two or more oscillation circuits for large amounts of energy is difficult; the governing is still more difficult and the danger in switching on or off is greater.

A means of overcoming such difficulties is shown in Figure 13. The oscillation circuit here runs starting from the point $a$ over condenser $5$, variable inductance $9$, spark gap $S$ and the two segments $(3^a$ and $4^a$) forming arms of a Wheatstone bridge, back to $a$. If the motor is connected by brushes $3$ and $4$ transversely to the two arms of the bridge as shown in the drawings, electromagnetic oscillations of equal sign are induced in the stator surfaces $1$ and $2$ and the motor does not revolve. If however, the brushes $3$ and $4$ are moved in common with the conducting wires $1$ and $2$ which connect the brushes with the stator poles a certain alteration or displacement of the polarity is obtained and the motor commences to revolve.

The maximum action will result if one brush $3$ comes on the central sparking contact $7$ and the other brush $4$ on the part $a$. They are however, usually in practice not brought on to the central contact $7$ but only held in the path of the bridge segments $4^a$ and $5^a$ in order not to connect the spark gaps with the motor oscillation circuit.

As however, the entire oscillation energy can thereby not act on the motor it is better to carry out the same system according to the diagram 14. The diagram 14 differs from the foregoing only by the motor not being directly metallically connected with the segments of the commutator, but only a primary coil $9$ which induces in a secondary coil $10$, current which feeds the motor $M$ and takes the place of the rotor. By this...
arrangement a good transforming action is obtained, a loose coupling and also an oscillation circuit without a spark gap.

In Figure 15 the motor is not purely inductively as in 14, but directly metallically branched off from the primary coil (at 2 and 4) after the principle of the auto-transformer.

In Figure 16 instead of an inductance a condenser 6 is in similar manner, and for the same object inserted between the segments 3 and 4. This has the advantage that the segments need not be made of solid metal but may consist of spiral coils whereby a more exact regulation is possible and further motors of high inductance may be employed.

The arrangements of Figures 17, 18 and 19 may be employed for use with resonance and particularly with induction condenser motors; between the large stator induction condenser surfaces, small reversing pole condensers are connected, which, as may be seen from Figures 17, 18 and 19 are led together to earth. Such reversing poles have the advantage that with large quantities of electrical energy the spark formation between the separate oscillation circuits ceases.

Figure 10 shows a further method which prevents electromagnetic oscillations of high number of alternations formed in the oscillation circuit striking back to the aerial conductor. It is based on the well known principle that a mercury lamp, one electrode of which is formed of mercury, the other of solid metal such as steel allows an electric charge to pass in only one direction from the mercury to the steel and not vice versa. The mercury electrode of the vacuum tube N is therefore connected with the aerial conductor and the steel electrode with the oscillation circuit. From this it results that charges can pass only from the aerial through the vacuum tube to the oscillation circuit, but not vice versa. Oscillations which are formed on being transformed in the oscillation circuit cannot pass to the aerial conductor.

In practice these vacuum tubes must be connected behind an electromagnet, as the latter alone affords no protection against the danger of lightning.

As regards the use of spark gaps, all arrangements as used for wireless telegraphy may be used. Of course the spark gaps in large machines must have a sufficiently large surface. In very large stations they are cooled in liquid carbonic acid or better still in liquid nitrogen or hydrogen; in most cases the cooling may also take place by means of liquefied low homologues of the metal series or by means of hydrocarbons the freezing point of which lies at between –90° C. and –40° C. The spark gap casing must also be insulated and be of sufficient strength to be able to resist any pressure which may arise. Any undesirable excess super-pressure which may be formed must be automatically let off. I have employed with very good results mercury electrodes which were frozen in liquid carbonic acid, the cooling being maintained during the operation from the outside through the walls.

Figure 20 is one of the simplest forms of construction of an aerial network in combination with collectors, transformers and the like illustrated diagrammatically. E is here the earth wire, 8 the safety spark gap, 7 the working spark gap, 1 and 2 the stator surfaces of the motor, 5 a condenser battery, 8 the protective magnet which is connected with the coil in the aerial conductor, A to A’ aerial antenna with collecting balloons, N horizontal collecting or connecting wires from which to the centre a number of connections run.

The actual collectors consist of metal sheaths preferably made of an aluminium magnesium alloy, and are filled with hydrogen or helium and are attached to copper plated steel wires. The size of the balloon is selected so that the actual weight of the balloon and the weight of the conducting wire is supported thereby. On the top of the balloon aluminium spikes, made and gilded in a special manner hereinafter described, are arranged in order to produce a conductor action. Small quantities of radium preparations, more particularly polonium-ionium or mesothorium preparations considerably increase the ionization, and therewith the action of these collectors.

In addition to metal balloons, fabric balloons which are superficially metal coated according to Schoop’s metal spraying process, may however also be employed. A metallic surface may also be produced by lacquering with metallic bronzes, preferably according to Schoop’s spraying process or lacquering with metallic bronze powders in two electrical series of widely different metals, because thereby the collecting effect is considerably increased.

Instead of the ordinary round balloons, elongated, cigar shaped ones may be employed. In order also to utilize the frictional energy of the wind, patches or strips of non-conducting substances which produce electricity by friction, may be attached to the metallized balloon surfaces. The wind will impart a portion of its energy in the form of frictional electricity, to the balloon casing, and thereby the collecting effect is substantially increased.

In practice however, very high towers (up to 300 metres is fully admissible) may be employed as antennas. In these towers copper tubes rise freely further above the top of the tower. A gas lamp secured
against the wind is then lit at the point of the copper tube and a netting is secured to the copper tube over the flame of this lamp to form a collector. The gas is conveyed through the interior of the tube up to the summit. The copper tube must be absolutely protected from moisture at the place at which it enters the tower and also rain must be prevented running down the walls of the tower which might lead to a bad catastrophe. This is done by bell shaped enlargements which expand downwards, being arranged in the tower in the form of high voltage insulators of Siamese pagodas.

Special attention must be devoted to the foundations of such towers. They must be well insulated from the ground, which may be obtained by first embedding a layer of concrete in a box form to a sufficient depth in the ground and inserting in this an asphalt lining and then glass bricks cast about 1 or 2 metres in thickness. Over this in turn there is a ferro-concrete layer in which alone the metal foot of the tube is secured. This concrete block must be at least 2 metres from the ground and be fully protected at the sides by a wooden covering, from moisture. In the lower part of the tower a wood or glass house for the large condenser batteries or for the motors may be constructed. In order to lead the earth connection to the ground water, a well insulated pit constructed of vitreous bricks must be provided. Several such towers are erected at equal distances apart and connected with a horizontal conductor. The horizontal connecting wires may either run directly from tower to tower or be carried on bell shaped insulators similar to those in use for high voltage conductors. The width of the network may be of any suitable size, and the connection of the motors can take place at any suitable places.

In order to collect large quantities of electricity from a few aerials it is well to provide the aerial conductor with batteries of condensers as shown in two methods of construction in Figures 21 and 22. In Figure 21 the batteries of condensers 5 are connected on the one hand with the aerial electricity collectors Z by the aerial conductor A, and on the other hand interconnected in series with an annular conductor from which horizontal conductors run to the connecting points C to which the earth wire is connected.

Figure 22 shows a similar arrangement. Should two such series of antenna rings be shown by a voltmeter to have a large difference of potential (for example, one in the mountains and one in the plain) or even of different polarity these differences may be compensated for by connecting sufficiently large condenser batteries (5, 5', 5'') by means of Majer star conductors D and D'. In Figure 23 a connection of three such rings of collectors to form a triangle with a central condenser battery is illustrated.

The condenser batteries of such large installations must be embedded in liquefied gases or in liquids freezing at very low temperatures. In such cases a portion of the atmospheric energy must be employed for liquefying these gases. It is also preferable to employ pressure. By this means the condenser surfaces may be diminished, and still allow for large quantities of energy to be stored, secure against breakdown. For smaller installations the immersing of the condensers in well insulated oil or the like suffices. Solid substances on the other hand cannot be employed as insulators.

The arrangement in the diagrams hitherto described was always such that the condenser batteries were connected with both poles directly to the aerial conductors. An improved diagram of the connections for obtaining atmospheric electricity for the condenser batteries has however, been found to be very advantageous, this arrangement consists in that they are connected by only one pole (unipolar) to the collecting network. Such a method of arrangement is very important, as by means of it a constant current and an increase of the normal weighing pressure or voltage is obtained. If for example a collecting balloon aerial which is allowed to rise to a height of 300 metres, shows 40,000 volts above earth voltage, in practice it has been found that the working voltage (with a withdrawal of the power according to the method hereinafter described by means of oscillating spark gaps and the like) is only about 400 volts. If however, the capacity of the condenser surfaces be increased, which capacity in the above mentioned case was equal to that of the collecting surface of the balloon aerials, to double the amount, by connecting the condenser batteries with only one pole, the voltage rises under an equal withdrawal of current up to and beyond 500 volts. This can only be ascribed to the favourable action of the connecting method.

In addition to this substantial improvement it has also been found preferable to insert double inductances with electromagnets and to place the capacities preferably between two such electromagnets. It has also been found that the useful action of such condensers can be further increased if an induction coil be connected as inductive resistance to the unconnected pole of the condenser, or still better if the condenser itself be made as an induction condenser. Such a condenser may be compared with a spring which when compressed carries in itself accumulated force, which it again gives off when released. In charging, a charge with reversed sign is formed at the pole.
other free condenser pole, and if through the spark gap a short circuit results, the accumulated energy is again given back since now new quantities of energy are induced at the condenser pole connected with the conductor network, which in fact charges with opposite signs to that at the free condenser pole. The new induced charges have of course the same sign as the collector network. The whole voltage energy in the aerial is thereby however increased. In the same space of time larger quantities of energy are accumulated than is the case without such inserted condenser batteries.

In Figures 24 and 25 two different diagrams of connections are more exactly illustrated. Figure 24 shows a collecting balloon and the diagram of the connections to earth. Figure 25 four collecting balloons and the parallel connection of the condenser batteries belonging thereto.

A is the collecting balloon made of an aluminium magnesium alloy (electron metal, magnalium) of a specific gravity of 1.8 and a thickness of plate 0.1 to 0.2 mm. Inside there are eight strong vertical ribs of T shaped section about 10 to 20 mm. in height and about 3 mm. in thickness with the projecting part directed inwards (indicated by a, b, c, d and so forth); they are riveted together to form a firm skeleton and are stiffened in a horizontal direction by two cross ribs. The ribs are further connected with one another internally and transversely by means of thin steel wires, whereby the balloon obtains great power of resistance and elasticity. Rolled plates of 0.1 to 0.2 mm. in thickness made of magnalium alloy are then either soldered or riveted on this skeleton so that a fully metallic casing with smooth external surface is obtained. Well silvered or coppered aluminium plated steel wires run from each rib to the fastening ring 2. Further, the coppered steel hawser L preferably twisted out of separate thin wires (shown in dotted lines in Figure 24) and which must be long enough to allow the balloon to rise in the desired height, leads to a metal roller or pulley 3 and from thence to a winch W, well insulated from the earth. By means of this winch, the balloon, which is filled with hydrogen, or helium, can be allowed to rise to a suitable height (300 to 5,000 metres) and brought to the ground for recharging or repairs.

The actual current is taken directly through a friction contact from the metal roller 3 or from the wire, or even from the winch or simultaneously from all three by means of brushes (3, 3A and 3B). Beyond the brush the conductor is divided, the paths being—firstly over 12 to the safety spark gap 8, from thence to the earth conductor E1, and secondly over electromagnet S1, point 13, to a second loose electromagnet having an adjustable coil S2, then to the spark gap 7 and to the second earth conductor E2. The actual working circuit is formed through the spark gap 7, condensers 5 and 6, and through the primary coil 9; here the static electricity formed by oscillatory discharges is accumulated and converted into high frequency electromagnetic oscillations. Between the electromagnets S1 and S2 at the crossing point 13, four condenser batteries are introduced which are only indicated diagrammatically in the drawings each by one condenser. Two of these batteries (16 and 18) are made as plate condensers and prolonged by regulating induction coils or spirals 17 and 19 while the two others (21 and 23) are induction condensers. As may be seen from the drawings each of the four condenser batteries 16, 18, 21, 23 is connected only by one pole to the aerial or to the collector conductor. The second poles 17, 19, 22, 24 are open. In the case of plate condensers having no inductive resistance an induction coil is inserted. The object of such a spiral or coil is the displacement of phase of the induction current by 90 periods, whilst the charging current of the condenser poles which lie free in the air, works back to the collector aerial. The consequence of this is that in discharges in the collector aerial the back inductive action of the free poles allows a higher voltage to be maintained in the aerial collecting conductor than would otherwise be the case. It has also been found that such a back action has an extremely favourable effect on the wear of the contacts. Of course the inductive effect may be regulated at will within the limits of the size of the induction coil, the length of the coil in action being adjustable by means of wire connection without induction (see Fig. 24, No. 20).

S1 and S2 may also be provided with such regulating devices in the case of S2 (illustrated by 11). If excess voltage be formed it is conducted to earth through the wire 12 and spark gap 8 or through any other suitable apparatus, since this formation would be dangerous for the other apparatus.

The action of these condenser batteries has already been hereinafore described.

The small circles on the collector balloon indicate places at which zinc amalgam or gold amalgam or other photoelectric acting metals in the form of small patches in extremely thin layers (.01 to .05 mm. in thickness) are applied to the balloon casing of light metal. Such metallic patches may also be applied to the entire balloon as well as in greater thickness to the conducting network. The capacity of the collector is thereby considerably strengthened at the surface. The greatest possible effect in collecting may be obtained by polonium amalgams and the like. On the surface of the...
collector balloon metal points or spikes are also fixed along the ribs, which spikes serve particularly for collecting the collector charge. Since it is well known that the resistance of the spikes is less the sharper the spike is, for this purpose it is therefore extremely important to employ as sharp spikes as possible. Experiments made as regards these have shown that the formation of the body of the spike or point also plays a large part. For example, spikes made of bars or rollers with smooth surfaces, have a many times greater point resistance as collector accumulator spikes than those with rough surfaces. Various kinds of spike bodies have been experimented with for the collector balloons hereinbefore mentioned. The best results were given by spikes which were made in the following way. Fine points made of steel, copper, nickel, or copper and nickel alloys, were fastened together in bundles and then placed as anode with the points in a suitable electrolyte (preferably in hydrochloric acid or nitrates of iron solutions) and so treated with weak current. 2 to 3 volts pressure. After 2 to 3 hours according to the thickness of the spikes or pins the points become extremely sharp and the bodies of the spikes have a rough surface. The bundle can then be removed and the acid washed off with water. The spikes are then placed as cathode in a bath consisting of solution of gold, platinum, iridium, paladium or wolfram salts or their compounds and coated at the cathode galvanically with a thin layer of precious metal, which must however be sufficiently firm to protect them from atmospheric oxidation.

Such spikes act at a 20 fold lower voltage almost as well as the best, and finest points made by mechanical means. Still better results are obtained if polonium or radium salts are added to the galvanic bath when forming the protective layer or coating. Such pins have a low resistance at their points and even at one volt and still lower pressures have an excellent collector action.

In Figure 24 the three unconnected poles are not connected with one another in parallel. That is quite possible in practice without altering the principle of the free pole. It is also preferable to interconnect in parallel to a common collector network, a series of collecting aerials.

Figure 25 shows a diagram for such an installation. A, A', A 3, A 4 are four metal collector balloons with gold or platinum coated spikes which are electrolytically made in the presence of polonium emanations or radium salts, which spikes or needles are connected over four electro-magnets S 5, S 6, S 7, S 8, through an annular conductor R. From this annular conductor four wires run over four further electromagnets S 5, S 6, S 7, S 8, to the connecting point 13. There the conductor is divided, one branch passing over 12 and the safety spark gap 8 to the earth at E 2; the other over inductive resistance J and working spark gap 7 to the earth at E 2. The working circuit, consisting of the condenser 5 and 6 and a resonance motor or a condenser motor M, such as hereinbefore described, is connected in proximity round the sparking gap section 7.

Instead of directly connecting the condenser motor of course the primary circuit for high frequency oscillatory current may also be inserted. The condenser batteries are connected by one pole to the annular conductor R and can be either inductionless (16 and 18) or made as induction condensers as shown by 21 and 23. The free poles of the inductionless condensers are indicated by 17 and 19, those of the induction condensers by 22 and 24. As may be seen from the drawings all these poles 17, 19, 21, 24 may be interconnected in parallel through a second annular conductor without any fear that thereby the principle of the free pole connection will be injured. In addition to the advantages already set forth the parallel connection also allows of an equalization of the working pressure in the entire collector network.

Suitably constructed and calculated induction coils 25 and 26 may also be inserted in the annular conductor of the free poles, by means of which a circuit may be formed in the secondary coils 27 and 28 which allows current produced in this annular condenser by fluctuations of the charges or the like appearances to be measured or otherwise utilized.

According to what has been hereinbefore stated separate collector balloons may be connected at equidistant stations distributed over the entire country, either connected directly with one another metallically or by means of intermediate suitably connected condenser batteries through high voltage conductors insulated from earth. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations and may in such form be coupled as a source of energy by means of a suitable method of connecting, various precautions being observed, and with special regulations. The wires leading from the collector balloons have hitherto been connected through an annular conductor without this endless connection, which can be regarded as an endless induction coil, being able to exert any action on the whole conductor system.

It has now been found that if the network conductor connecting the aerial collector balloons with one another is not made as a simple annular conductor, but preferably short circuited in the form of coils over a
condenser battery or spark gap or through thermionic tubes or valves or audions, then the total collecting network exhibits quite new properties. The collection of atmospheric electricity is thereby not only increased but an alternating field may be easily produced in the collector network. Further, the atmospheric electrical forces showing themselves in the higher regions may also be directly obtained by induction.

In Figures 26 and 28 a form of construction is shown on the basis of which the further foundations of the method will be more particularly explained.

In Figure 261, 2, 3, 4 are metal collector balloons, 5, 6, 7, 8 their metallic aerial conductors and I the actual collector network. This consists of five coils and is mounted on high voltage insulators in the air, on high voltage masts (or with a suitable construction of cable embedded in the earth). One coil has a diameter of 1 to 100 km, or more. S and S' are two protective electromagnets, P the second safety section against excess voltage, E its earth conductor and E1 the earth conductor of the working section. When an absorption of static atmospheric electricity is effected through the four balloon collectors, the current in order to reach the earth connection E1 must flow spirally through the collector network over the electromagnet S, primary induction coil 9, conductor 14, anode A of the audion tube, incandescent cathode K, as the way over the electromagnet and safety spark gap F offers considerably greater resistance. Owing to the fact that the accumulated current flows in one direction, an electromagnetic alternating field is produced in the interior of the collector network coil, whereby the whole free electrons are directed more or less into the interior of the coil. An increased ionization of the atmosphere is therefore produced. In consequence of this the points mounted on the collector balloon show a considerably reduced resistance and therefore increased static charges between the points on the balloon and the surrounding atmosphere are produced. The result of this is a considerably increased collector effect.

A second effect which could not be obtained otherwise is obtained by the electromagnetic alternating field which running parallel to the earth surface, acts more or less with a diminishing or increasing effect on the earth magnetic field, whereby in the case of fluctuations in the current a return induction current of reversed sign is always produced in the collector coil by earth magnetism. Now if, however, a constantly pulsating continuous alternating field is produced as stated in the above collector network I, an alternating current of the same periodicity is produced also in the collecting network coil. As the same alternating field is further transmitted to the aerial balloon, the resistance of its points is thereby considerably reduced, whilst the collector action is considerably increased. A further advantage is that positive electrons which collect on the metal surfaces during the conversion into dynamic current produce a so-called drop of potential of the collector area. As an alternating field is present, the negative ions surrounding the collector surfaces, when discharge of the collector surfaces takes place produce by the law of induction, an induction of reversed sign on the collector surface and so forth (that is to say again a positive charge). In addition to the advantages hereinbefore set forth, the construction of connecting conductors in coil form when of sufficiently large diameter, allows of a utilization of energy arising in higher regions also in the simplest way. As is well known, electric discharges frequently take place at very great elevations which may be observed, such as St. Elmo's fires or northern lights. These energy quantities have not been able to be utilized up to now. By this invention all these kinds of energy, as they are of an electromagnetic nature and the direction of the axis of the collector coils stands at right angles to the earth's surface, can be more or less absorbed in the same way as a receiver in wireless telegraphy absorbs waves coming from a far distance. With a large diameter of the spiral it is possible to connect large surfaces and thereby to take up also large quantities of energy.

It is well known that large wireless stations in the summer months, and also in the tropics are very frequently unable to receive the signals in consequence of interruptions which are caused by atmospheric electricity, and this takes place with vertical coils of only 40 to 100 m. diameter. If on the contrary horizontal coils of 1 to 100 km. diameter be employed very strong currents may be obtained through discharges which are constantly taking place in the atmosphere. Particularly in the tropics or still better in the polar regions where the northern lights are constantly present, large quantities of energy may probably be obtained in this way. A coil with several windings should act the best. In similar manner any alteration of the earth magnetism should act inductively on such a coil.

It is not at all unlikely that earthquakes and spots on the sun will also produce an induction in such collector coils of sufficient size. In similar manner this collector conductor will react on earth currents more particularly when they are near the surface of the earth or even embedded in the earth. By combining the previous kind of current collectors so far as they are adapted for
the improved system with the improved possibilities of obtaining current the quantities of free natural energy which are to be obtained in the form of electricity are considerably increased.

In order to produce in the improved collector coil uniform current oscillations of an undamped nature so-called audion high vacuum or thermionic tubes of suitable connection are employed instead of the previously known spark gaps (Fig. 26, Nos. 9–18). The main aerial current flows through electromagnet S (which in the case of a high number of alternations is not connected here but in the earth conductor B') and may be conveyed over the primary coils in the induction winding through wire 14 to the anode A of the high vacuum grid tube. Parallel with the induction resistance 9 a regulating capacity of suitable size, such as condenser 11 is inserted. In the lower part of the vacuum grid tube is arranged the incandescent filament or the cathode K which is fed through a battery B. From the battery B two branches run, one to the earth conductor E and the other through battery B' and secondary coil 10 to the grid anode g in the vacuum tube. By the method of connections shown in dotted lines, a desired voltage at the grid electrode g may also be produced through the wire 17 which is branched off from the main current conductor through switches 16 and some small condensers (a, b, c, d) connected in series, and conductor 18, without the battery B' being required.

The action of the entire system is somewhat as follows:

On the connecting conductor of the aerial collector network being short circuit to earth, the condenser pole 11 is charged and slightly damped oscillations are formed in the short circuited existing oscillation circuit formed of the condenser 11 and self inductance 9. In consequence of the coupling through coil 10, fluctuations of voltage take place in the grid circuit 15 with the same frequency, which, fluctuations in turn influence the strength of the electrode current passing through the high vacuum amplying tube and thus produce current fluctuations of the same frequency in the anode circuit. A permanent supply of energy to the oscillation circuits 9 and 10 consequently takes place, until a condition of balance is set up, in which the consumed oscillation energy is equal to that absorbed. Thereby constant undamped oscillations are now produced in the oscillation circuits 9–11.

For regular working of such oscillation producers high vacuum strengthening tubes are necessary and it is also necessary that the grid and anode voltages shall have a phase difference of 180° so that if the grid is negatively charged, then the anode is positively charged and vice versa. This necessary difference of phase may be obtained by most varied connections, for example, by placing the oscillation circuit in the grid circuit or by separating the oscillation circuit and inductive coupling from the anodes and the grid circuit and so forth.

A second important factor in this way of converting static atmospheric electricity into undamped oscillations is that care must be taken that the grid and anode voltages have a certain relation to one another; the latter may be obtained by altering the coupling and a suitable selection of the self-induction in the grid circuit, or as shown by dotted lines 17, 16, 15 by means of a larger smaller number of condensers of suitable size connected in series; in this case the battery B may be omitted. With a suitable selection of the grid potential a glow discharge takes place between the grid g and the anode A, and accordingly at the grid there is a cathode drop and a dark space is formed. The size of this cathode drop is influenced by the ions which are emitted in the lower space in consequence of shock ionization of the incandescent cathodes K and pass through the grid in the upper space. On the other hand the number of the ions passing through the grid is dependent on the voltage between the grid and the cathode. Thus if the grid voltage undergoes periodic fluctuations (as in the present case) the amount of the cathode drop at the grid fluctuates and consequently the internal resistance of the tube correspondingly fluctuates, so that when a back coupling of the feed circuit with the grid circuit takes place, the necessary means are afforded for producing undamped oscillations and of taking current, according to requirements from the collecting conductor.

The frequency of the undamped oscillations produced is with a suitably loose coupling equal to the self frequency of the oscillation circuits 9 and 10. By a suitable selection of the self induction of the coil 9 and capacity 11 it is possible to extend from frequencies which produce electromagnetic oscillations of only a few meters wave length down to the lowest practical alternating current frequency. For large installations a suitable number of frequency producing tubes in the form of the well known high vacuum transmission tubes of .5 to 2 kw. in size may be connected in parallel so that in this respect no difficulty exists.

The use of such tubes for producing undamped oscillations, and also the construction and method of inserting such transmission tubes in an accumulator or dynamo circuit is known and also that such oscillation producing tubes only work well at voltages of 1,000 up to 4,000 volts, so that on the contrary their use at lower voltages is
considerably more difficult. By the use of high voltage static electricity this method of producing undamped oscillations as compared with that through spark gaps must be regarded as an ideal solution particularly for small installations of outputs of from 1 to 100 kw.

But the application of safety spark gaps, with internutation of electro-magnets, not only is short circuiting avoided but also the taking up of current is regulated. Oscillation producers inserted in the above way form a constantly acting electromagnetic alternating field in the collector coil, whereby as already stated, a considerable accumulating effect takes place. The withdrawal wire or working wire is connected at 12 and 13, but current may be taken by means of a secondary coil which is firmly or movably mounted in any suitable way inside the large collector coil, i.e., in its electromagnetic alternating field, so long as the direction of its axis runs parallel with that of the main current collecting coil.

In producing undamped oscillations of a high frequency (50,000 per second and more) in the oscillation circuits 9 and 11, electromagnets S and S' must be inserted if the high frequency oscillations are not to penetrate the collector coil, between the oscillation producers and the collector coil. In all other cases they are connected shortly before the earthing (as in Figs. 27 and 28).

In Figure 27 a second method of construction of the connecting conductor of the balloon aerials is illustrated in the form of a coil. The main difference consists in that in addition to the connecting conductor I another annular conductor II is inserted parallel to the former on the high voltage masts in the air (or embedded as a cable in the earth) but both in the form of a coil. The connecting wire of the balloon aerials is indicated as a primary conductor and also as a current producing network; the other is the consumption network and is not in unipolar connection with the current producing network.

In Figure 27 the current producing network I is shown with three balloon collectors 1, 2, 3 and aerial conductors 4, 5, 6; it is short circuited through condenser 19 and inductance 9. The oscillation forming circuit consists in this diagram of spark gap f, inductance 10, and condenser 11; the earth wire E1 is connected to earth over electromagnet S1. F is the safety spark gap which is also connected to earth through a second electromagnet S at E. On connecting up the condenser circuit 11 this is charged over the spark gap f whereby an oscillatory discharge is formed. This discharging current acts through inductance 10 on the inductively coupled secondary 9, whereby in the producing network a modification of the potential of the condenser 19 is produced. The consequence of this is that oscillations in the secondary circuit II, which has a smaller number of windings and a less resistance, the voltage of which, according to the proportion of the number of windings and of the ohmic resistance, is considerably lower whilst the current strength is greater.

In order to convert the current thus obtained into current of an undamped character, and to tune its wave lengths, a sufficiently large regulatable capacity 20 is inserted between the ends 12 and 15 of the secondary conductor II. Here also current may be taken without an earth conductor, but it is advisable to insert a safety spark gap E2 and to connect this with the earth over an electromagnet S2.

The producer network may be connected with the working network II over an inductionless condenser 21 or over an induction condenser 22, 23. In this case the secondary conductor is unipolarly connected with the energy conductor.

In Figure 28 the connecting conductor between the separate accumulator balloons is carried out according to the autotransformer principle. The collecting coil connects four aerial balloons 1, 2, 3, 4; the windings of which are not made side by side but one above the other. In Figure 28 the collector coil I is shown with a thin line, the metallically connected prolongation coils II with a thick line. Between the ends I and II' of the energy network I a regulating capacity 19 is inserted. The wire II' is connected with the output wire and with the spark gap F.

As transformer of the atmospheric electricity an arrangement is employed which consists in using rotary pairs of condensers in which the one stator surface B is connected with the main current, whilst the other A is connected with the earth pole. Between these pairs of short circuited condensers are caused to rotate from which the converted current can be taken by means of two collector rings and brushes, in the form of an alternating current, the frequency of which is dependent on the number of balloons and the revolutions of the rotor. As the alternating current formed in the rotor can act, in this improved method of connection described in this invention, through coils 10 on the inductance 9, an increase or diminution of the feed current in I can be obtained according to the direction of the current by back induction. Current oscillations of uniform rhythm thereby result in the coil shaped windings of the producer network.

As the ends of this conductor are short cir-
cuit through the regulatable condenser 19, these rhythms produce short-circuited undamped oscillations in the energy conductor. The periodicity and wave lengths of which oscillations can be adjusted according to desire by altering the capacity 19 to a given wave length and therewith also to a given frequency. These currents may also be employed in this form directly as working current, through the conductors II and III. By inserting the condenser 20 a connection between these conductors may also be made, whereby harmonic oscillations of desired wave length are formed. By this means quite new effects as regards current distribution are obtained. The withdrawal of current can even take place without direct wire connection if, at a suitable point in the interior of the producing network (quite materially whether this has a diameter of 1 or 100 km.) a coil tuned to these wave lengths and of the desired capacity is firmly or movably mounted in the aerial conductor in such a way that the axial direction is in parallel with that of the collector coil. In this case a current is induced in the producing network, the size of which is dependent on the total capacity and resistance and also on the periodicity employed. A possibility is thereby afforded in future, of taking energy from the producer network by wireless means. As thereby in addition to atmospheric electricity also magnetic earth currents and the energy from the higher atmosphere (at least partially) may be simultaneously obtained, this last system for collecting the atmospheric energy is of particular importance for the future.

Of course everywhere instead of spark gaps suitable grid vacuum tubes may be employed as producers for undamped oscillations. The separate coils of the producer net-work with large diameters may be connected with one another through separate conductors all in parallel or all in series or in groups in series. By regulating the number of oscillations and also the extent of the voltage more or less large collector coils of this kind may be employed. The coils may also be divided spirally over the entire section. The coils may be carried out in annular form or also in triangular, quadrangular, hexagonal or octagonal form.

Of course wires may be carried from a suitable place to the centre or also laterally which serve the current waves as guides. This is necessary when the currents have to be conducted over mountains and valleys and so forth. In all these cases the current must be converted into a current of suitable periodicity.

As already hereinbefore mentioned separate collecting balloons may be directly metalically interconnected at equidistant stations distributed over the entire country or may be connected by interpolation of suitable condenser batteries by means of high voltage conductors. The static electricity is converted through a spark gap into dynamic energy of a high number of oscillations, and could then in such form, with a suitable arrangement of the connections, observing various measures of precaution, be employed as source of energy after separate or special regulation.

According to this invention in order to increase the collecting effect of the balloon in the aerial collector conductor or in the earth wire, radiating collectors are employed. These consist either of incandescent metal or oxide electrodes in the form of vacuum grid tubes, or electric arcs (mercury and the like electrodes) Nernst lamps, or finally flames of various kinds may be simply connected with the respective conductor.

It is well known that energy can be drawn off from a cathode consisting of an incandescent body opposite an anode charged with positive electricity (vacuum grid tube). Hitherto however, a cathode was always first directly placed opposite an anode, and secondly the system always consisted of a closed circuit.

Now if we dispense with the ordinary ideas in forming light or flame arcs in which a cathode must always stand directly opposite an anode, and if we place an incandescent cathode opposite an anode charged to a high potential or another body freely floating in the air, or regard the incandescent cathode only as a source of unipolar discharge (which represent group and point discharges in electro-static machines similar to unipolar discharges), it may be ascertained that incandescent cathodes and less perfectly all incandescent radiators, flames and the like admit of relatively large current densities and allow large quantities of electric energy to radiate into the open space in the form of electron streams as transmitters.

The object of this invention is as described below, if such incandescent oxide electrodes or other incandescent radiators or flames are not freely suspended in space but connected metallically with the earth so that they can be charged with negative terrestrial electricity, these radiators possess the property of absorbing the free positive electrical charges contained in the air space surrounding them (that is to say of collecting them) and conducting them to earth. They can therefore, serve as collectors and have, in comparison to the action of the spikes, or points, a very large radius of action R; the effective capacity of these collectors is much greater than the geometrical capacity (R_o-) calculated in an electro-static sense.

Now as our earth is surrounded as is well
known, with an electro-static field and the
difference of potential
\[ \Delta V \]
\[ \Delta h \]
of the earth field according to the latest
investigations, is in summer about 60 to
100 volts and in winter 300 to 500 volts per
metre of difference in height (\( \Delta h \)), a simple
calculation gives the result that when such a
radiation collector or flame collector is ar-
ranged for example on the ground, and a
second one is mounted vertically over it at
a distance of 2,000 metres and both are con-
nected by a conducting cable, there is a dif-
ference of potential in summer of about
2,000,000 volts and in winter even of 6,000,-
000 volts and more.

According to Stefan Boltzmann's law of
radiation, the quantity of energy which an
incandescent surface (temperature \( T \)) of 1
sq. cm. radiates in a unit of time into the
open air (temperature \( T_0 \)) is expressed by
the following formula:

\[ S = \frac{\varepsilon (T^4 - T_0^4)}{\text{watt/sq. cm.}} \]

and the universal radiation constant \( \varepsilon \) is
determined by the latest researches of Ferry
(Annales de Chimie et de physique 17 page
267 (1909)) equal to 5.80x10^{-18} \text{watt/sq. cm.}

Now if an incandescent surface of 1 sq.
\text{cm.} shows, as compared with the surround-
ing space a periodic fall of potential \( \Delta V \) it
radiates (independent of the current direc-
tion, that is to say of the sign) in accord-
ance with the above formula, for example at
a temperature of 3735° C. an energy of 1.6
kw. per sq. cm. per second. As for the
radiation the same value can be calculated
for the collection of energy, but reversed.
Now as carbon electrodes at the temperature
of the electric are support on the current
basis a current density up to from 60 to 65
ammperes per sq. cm. no difficulties will result
in this direction in employing radiating col-
lectors as accumulators.

If the earth be regarded as a cosmically
insulated condenser in the sense of geometri-
cal electro-statics \( e \) there results from the
geometric (compare Ewald Rasch, "das
elektrische Bogenlicht") the electric arc
light (page 169) capacity of the earth ac-
ccording to Chwolson:

For negative charging 1.3x10^{10} Coulomb

For negative potential \( V=10x10^8 \) volts.

From this there results however, \( EJT=24.7
\times10^4 \) watt/Sec. Now if it is desired to
make a theoretic short circuit through an
earthen flame collector this would represent
an electric total work of about 79,500
10^4 kilowatt years. As the earth must be
regarded as a rotating mechanism which is
thermo-dynamically, electromagnetically,
and also kinematically coupled with the sun
and stars system by cosmic radiations and
gravitation a diminution of the electric
energy of the earth field is not to be feared.
The energies which the incandescent col-
lectors would withdraw from the earth field
can only cause by the withdrawal of motor
work a lowering of the earth temperature
(temperature \( T_0=300 \)) and reduce this to
that of the world space (\( T_0=0 \)) by using
the entire energy. This is however not the
case as the earth does not represent a cos-
mically entirely insulated system. On the
contrary there is conveyed to the same ac-
cording to the recent value corrected by
Ferry for the solar constants through the
radiation from the sun an energy of 18,500
\times10^{10} \text{kw.} Accordingly any lowering of
the earth temperature (\( T_0 \)) without a simul-
taneous lowering of the sun's temperature
(\( T_0 \)) would contradict Stefan Boltzmann's
law of radiation.

\[ S = \delta (T_0^4 - T_0^4) \]

From this it must be concluded that if the
earth temperature (\( T_0 \)) sinks, the total
radiation \( S \) absorbed by the earth increases,
and further also that the secular speed of
cooling of the earth is directly dependent
on that of the sun and the other radiators
cosmically coupled with the sun and is con-
ected most closely with these.

The incandescent radiation collectors
may, according to this invention, be em-
ployed for collecting atmospheric electricity
if they (1) are charged with the negative
earth electricity (that is to say when they
are directly connected by means of a meta-
llic conductor with the earth) and (2) if
large capacities (metal surfaces) charged
with electricity are mounted opposite them
as positive poles in the air. This is regard-
ed as the main feature of the present in-
vention as without these inventive ideas it
would not be possible to collect with an
incandescent collector, sufficiently large quan-
tities of the electrical charges contained
in the atmosphere as technology requires;
the radius of action of the flame collectors
would also be too small, especially if it be
considered that the very small surface den-
sity (energy density) \( \varepsilon \) about \( =2x10^4 \text{watt/cm.} \)

St. E, per sq. cm.) does not allow of large
quantities of charge being absorbed from
the atmosphere.

a) Calculated according to Poisson's calcu-
lation;

\[ \Delta V = -\frac{4\pi\varepsilon}{\delta V} \]
as here the alteration of the
potential or potential gradients only takes
place in the direction of the normal, this
calculation assumes the simple form

\[ \delta V = \frac{1}{4\pi\varepsilon}\left(\frac{P_V}{\delta V}\right) \]

It has already been proposed to em-
ploy flame collectors for collecting at-
mospheric electricity and it is known that
their collecting effect is substantially greater opposite the points. It is however, not known that the quantities of current which could lietherto be obtained are too small for technical purposes. According to my experiments the reason for this is to be found in the too small capacities of the collector conductor poles. If such flame or radiating collectors have no or only small positive surfaces, their radius of action for large technical purposes is too small. If the incandescent collectors be constantly kept in movement in the air they may collect more according to the speed of the movement, but this is again not capable of being carried out in practice.

By this invention the collector effect is considerably increased by a body charged with a positive potential and of the best possible capacity being also held floating (without direct earth connection) opposite such an incandescent collector which is held floating in the air at a desired height. If for example, a collecting balloon of sheet metal or of metalized balloon fabric be caused to mount to 300 up to 3,000 metres in the air and as positive pole it is brought opposite such a radiating collector connected by a conductor to earth, quite different results are obtained.

The metallic balloon shell (with a large surface) is charged to a high potential by the atmospheric electricity. This potential is greater the higher the collecting balloon is above the incandescent collector. The positive electricity acts concentrated on the anode floating in the air as it is attracted through the radiation shock ionization, proceeding from the incandescent cathode.

The consequence of this is that the radius of action of the incandescent cathode collector is considerably increased and thereby also the collecting effect of the collecting balloon surface. Further the large capacity of the anode floating in the air plays an important part because it allows of the taking of large charges, and thereby a more uniform current is obtained even when there is a large consumption; this cannot be the case with small surfaces.

In the present case the metallic collecting balloon is a positive anode floating in the air and the end of the earth conductor of this balloon serves as positive pole surface opposite the surface of the radiating incandescent cathode, which in turn is charged with negative earth electricity being conductively connected to earth.

The process may be carried out by two such contacts (negative incandescent cathode and anode end of a capacity floating in the air) a condenser and an inductive resistance being switched on in parallel, whereby simultaneously undamped oscillations may be formed.

In very large installations it is advisable to connect two such radiating collectors in series. Thus an arc light incandescent cathode may be placed below on the open ground and an incandescent cathode which is heated by special electro-magnetic currents be located high in the air. Of course for this the special vacuum Liebig tubes with or without grids may also be employed. An ordinary arc lamp with oxide electrodes may be introduced on the ground and the positive pole is not directly connected with the collecting balloon, but through the upper incandescent cathode or over a condenser. The method of connecting the incandescent cathode floating in the air may be seen in Figs. 29-33.

B is the air balloon, K a Cardan ring (connection with the hawser) C the balloon, L a good conducting cable, P a positive pole, N negative incandescent cathode, and E earth conductor.

Fig. 29 represents the simplest form of construction. If electric oscillations are produced below on the ground by means of a carbon arc lamp or in other suitable way a considerably greater electric resistance is opposed to that in the direct way by inserting an electrical inductive resistance R. Consequently between P and N a voltage is formed, and as, over N and P only an inductionless ohmic resistance is present, a spark will spring over so long as the separate induction co-efficients and the like are correctly calculated. The consequence of this is that the oxide electrode (carbon or the like) is rendered incandescent and then shows as incandescent cathode an increased collecting effect. The positive poles must be substantially larger than the negative in order that they may not also become incandescent. As they are further connected with the large balloon area which has a large capacity and is charged at high voltage, an incandescent body which is held floating in the air and a positive pole which can collect large capacities is thereby obtained in the simplest way. The incandescent cathode is first caused to become incandescent by means of separate energy produced on the earth, and then maintained by the energy collected from the atmosphere.

Fig. 30 only shows the difference that instead of a round balloon a cigar shaped one (of metal or metalized fabric) may be employed and also a condenser is inserted between the incandescent cathode and the earth conductor so that a short circuited oscillation circuit over P, N 5 and 9 is obtained. This has the advantage that quite small quantities of electricity cause the cathode to become incandescent and much larger cathode bodies may be rendered incandescent.

In this form of construction both the
candescem cathode and also the positive electrode may be enclosed in a vacuum chamber as may be seen in Fig. 32. A cable L is carried well insulated through the cover of a vessel and ends in a condenser disc 5. The cover is arched in order to keep off the rain. The vessel is entirely or partially made of magnetic metal and well insulated inside and outside. Opposite the disc 5 another disc 6 and on this again a metallic positive pole of the vacuum tube g with the incandescent cathode (oxide electrode) N is arranged. The negative electrode is on the one hand connected with the earth conductor E, and on the other hand with the inductive resistance 9 which is also connected with the cable L with the positive pole and wound round the vessel in coils. The action is exactly the same as that in Fig. 29 only instead of an open incandescent cathode as in Fig. 29, it is employed. As in such collectors only small bodies can be brought to incandescence in large installations a plurality of such vacuum tubes must be inserted in proximity to one another. According to the previous constructions Figs. 31 and 33 are quite self evident without further explanations.

Figs. 34-37 represent further diagrams of connections over radiating and flame collectors, and in fact, how they are to be arranged on the ground. Fig. 34 shows an arc light collector with oxide electrodes for direct current and its connection; Fig. 35 a similar one for alternating current. Fig. 36 an incandescent collector with a Nernst lamp and Fig. 37 a similar one with a gas flame.

The positive pole 1 of the radiating collector is always directly connected to the aerial collecting conductor A. In Fig. 34 this is further connected over the condenser battery 5 with a second positive electrode 3. The direct current dynamo b produces current which flows over between the electrodes 3 and 2 as an arc light. On the formation of an arc the negative incandescent electrode 2 absorbs electricity from the positive poles standing opposite it and highly charged with atmospheric electricity and conveys the same to the working circuit. The spark gap 7, inductive resistance 9 and induction coil 10 are like the ones previously described. The protective electromagnet S guards the installation against earth circuiting, the safety spark gap 8 from excess voltage or overcharging.

In Fig. 35 the connection is so far altered that the alternating current dynamo feeds the exciting coil 11 of the induction condenser. 12 is its negative and 13 its positive pole; if the coil 3 on the magnet core of the dynamo is correctly calculated and the periodicity of the alternating current is sufficiently high an arc light can be formed between the two poles 1 and 2. As the cathode 2 is connected with the negatively charged earth, and therefore always acts as a negative pole, a form of rectification of the alternating current produced by the dynamo 8 is obtained, the second half of the period is always suppressed. The working circuit may be carried out in the same way as in Fig. 34; the working spark gap 7 may however be dispensed with, and instead thereof between the points a and m a condenser 3 and an inductive resistance 9 may be inserted from which the current is taken inductively.

Fig. 36 represents a form of construction similar to Fig. 34 only that here instead of an arc lamp a Nernst incandescent body is employed. The Nernst lamp is fed through the battery 3. The working section is connected with the negative pole, the safety spark gap with the + poles. The working spark gap 7 may also be dispensed with and the current for it taken at 12 over the oscillation circuit 5, 11 (shown in dotted lines).

Flame collectors (Fig. 37) may also be employed according to this invention. The wire network 1 is connected with the aerial collector conductor A and the burner with the earth. At the upper end of the latter, long points are provided which project into the flame. The positive electrode is connected with the negative over arc 8 and the induction coil 9 with the earth.

The novelty in this invention is firstly, the use of incandescent cathodes opposite positive poles which are connected with large metallic capacities as automatic collecting surfaces, (2) the connection of the incandescent cathodes with the earth whereby, in addition to the electricity conveyed to them from the battery or machine which causes the incandescent, also the negative charge of the earth potential is conveyed, and (3) the connection of the positive and negative poles of the radiating collectors over a condenser circuit alone or with the introduction of a suitable inductive resistance, whereby simultaneously an oscillatory oscillation circuit may be obtained. The collecting effect is by these methods quite considerably increased.

I declare that what I claim is:

1. An electrical energy generating system, comprising a conducting surface for static charges, means to support same at a distance above the earth, a conductor leading to the earth level, a spark gap associated with said conductor to convert electrostatic charges into electromagnetic high frequency oscillations means to supply said electromagnetic energy to a net work, and a spark gap of greatly increased relative resistance in parallel therewith.

2. An electrical energy generating system
comprising a conductor, means to support same above the earth level, an inductance therein, a spark gap associated with said conductor, a second spark gap of much higher relative resistance in parallel therewith and an energy receiving circuit coupled with the spark gap of lesser resistance.

3. An electrical energy generating system comprising a collecting surface, means to support same above the earth level, a conductor connecting said collecting surface with the earth level, a choke in said conductor, an electromagnetic resistance converting electrostatic energy to electromagnetic energy, a safety higher resistance in parallel therewith and a net work coupled with the conversion resistance of lesser value.

4. An electrical energy generating system comprising electric conductors spaced above the earth to form electromagnetic oscillating circuits, conductors connecting to earth level, electrostatic to electromagnetic energy conversion means therein, a safety high electrostatic resistance in parallel therewith and means to alter the electromagnetic characteristic of the circuits.

5. An electrical energy generating system comprising in combination a static collecting surface arranged above the earth, conductors connecting to earth level, a pair of spark gaps in parallel of different electrostatic resistance, a utilization net work shunted across the spark gap of lesser resistance and an electromagnetic choke in said conductors.

6. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance, connected thereto and a closed electric oscillation circuit in shunt across the gap of lesser resistance.

7. An electrical energy generating system comprising an open circuit energy collecting aerial, a pair of sparking gaps in parallel of widely different resistance connected thereto, a closed electric oscillation circuit in shunt across the gap of lesser resistance, a plurality of electrostatic collecting surfaces, means to connect said collecting surfaces in parallel in groups and means to connect said groups symmetrically with said aerial.

In witness whereof, I have hereunto signed my name this 30 day of Dec., 1920, in the presence of two subscribing witnesses.

HERMANN PLASON.

Witnesses:

H. F. Armstrong,
W. H. Beeston.
THE ELECTRICAL SIGNALS OF PLANETARY ORIGIN
NIKOLA TESLA

AND

THE PLANETARY RADIO SIGNALS

By

Kenneth L. Corum and James F. Corum, Ph.D.

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"My ear barely caught signals coming in regular succession which could not have been produced on earth . . ."

Nikola Tesla, 1919

"We are getting messages from the clouds one hundred miles away, possibly many times that distance. Do not leak it to the reporters." Nikola Tesla, 1899

"My measurements and calculations have shown that it is perfectly practicable to produce on our globe, by the use of these principles, an electrical movement of such magnitude that, without the slightest doubt, its effect will be perceptible on some of our nearer planets, as Venus and Mars. Thus, from mere possibility, interplanetary communication has entered the stage of probability." Nikola Tesla, 1900

"Movements on instrument repeated many times. Concludes it to be a message from another planet." Newspaper Interview, 1901

"I did not state that I had obtained a message from Mars, I only expressed my conviction that the disturbances that I obtained were of planetary origin." Nikola Tesla, 1901

"The feeling is constantly growing on me that I had been the first to hear the greetings of one planet to another." Nikola Tesla, 1901

"I refer to the strange electrical disturbances, the discovery which I announced six years ago. At that time I was only certain that they were of planetary origin. Now, after mature thought and study, I have come to the positive conclusion that they must emanate from Mars." Nikola Tesla, 1907

"To be sure, we have no absolute proof that Mars is inhabited... Personally, I base my faith on the feeble planetary electrical disturbances which I discovered in the summer of 1899, and which, according to my investigations, could not have originated from the sun, the moon, or Venus. Further study since has satisfied me they must have emanated from Mars." Nikola Tesla, 1909

"During my experiments there [Colorado Springs, 1899], Mars was at a relatively small distance from us and, in that dry and rarefied air, Venus appeared so large and bright that it might have been mistaken for one of those military signaling lights... I came to the conclusion that [Mars] was sufficient to exert a noticeable influence on a delicate receiver of the kind I was perfecting... my ear barely caught signals coming in regular succession which could not have been produced on earth, caused by any solar or lunar action or by the influence of Venus, and the possibility that they might have come from Mars flashed upon my mind." Nikola Tesla, 1919

"The arrangement of my receiving apparatus and the character of the disturbances recorded precluded the possibility of their being of terrestrial origin, and I also eliminated the influence of the sun, moon and Venus. As I announced, the signals consisted in a regular repetition of numbers, and subsequent study convinced me that they must have emanated from Mars, this planet having been just then close to the earth." Nikola Tesla, 1921

"Twenty-two years ago, while experimenting in Colorado with a wireless power plant, I obtained extraordinary experimental evidence of the existence of life on Mars. I had perfected a wireless receiver of extraordinary sensitiveness, far beyond anything known, and I caught signals which I interpreted as meaning 1 -- 2 -- 3 -- 4. I believe the Martians used numbers for communication because numbers are universal." Nikola Tesla, 1922

"In 1899, while experimenting with a wireless receiver of extraordinary sensitivity, I detected faint signals from Mars, our brother planet. I could not interpret the signals, but they seemed to suggest a numerical code, one - two - three - four." Nikola Tesla, 1935

[Fig. 1. Mars]
Fig. 1 MARS, son of Jupiter and Juno, god of War.
To the

American Red Cross

New York City.

The retrospect is glorious, the prospect inspiring: Much might be said of both. But one idea dominates my mind. This - my best, my dearest - is for your noble cause.

I have observed electrical actions, which have appeared inexplicable. Faint and uncertain though they were, they have given me a deep conviction and foreknowledge that ere long all human beings on this globe, as one, will turn their eyes to the firmament above, with feelings of love and reverence, thrilled by the glad news: "Brethren! We have a message from another world, unknown and remote. It reads: one ... two ... three ..."

Christmas 1900*

Nikola Tesla

* The date would appear to be Orthodox Christmas, January 7, 1900. Tesla died on this very night, exactly 43 years later. This is also the date of the last entry made in the Colorado Springs notes.
Prefatory Statement by the Authors:
The puzzling disclosures made by Nikola Tesla concerning the reception of extraterrestrial signals in 1899 have been a vexing dilemma and source of embarrassment to even the most ardent of Tesla's supporters in the scientific community. It is with some degree of trepidation that we even approach this subject. Initially, we were almost embarrassed to address such a controversial topic for fear of being misunderstood by our professional colleagues, or perhaps even causing damage to Tesla's reputation. However, we believe that the investigation reported on below will resolve specific technical objections to Tesla's assertions, and will lend strong support to the scientific credibility of Tesla's profound contributions to science and engineering. This paper is a brief summary of an 81 page engineering report from 1996 documenting the detailed analysis. As we approach the next Martian encounter (Mars will be only 34.6 million miles away on August 27, 2003 - the closest since 1719) our thoughts again turn to the faint radio emissions detected by Tesla in 1899.

NIKOLA TESLA AND THE PLANETARY RADIO SIGNALS

by K.L. Corum and J.F. Corum, Ph.D.

"Even these star-gazers stonish't are... and curse their lying books." Edmund Spenser, Faerie Queene, Bk. 7, Canto7

§ 1.0 Introduction.
Surrounded by a cloud of sensationalism, the controversial question of cosmic radio signals has probably spawned the greatest test of Tesla's credibility among professional scientists. In spite of the fact that Lord Kelvin, himself, stood with his old friend and proclaimed that he was in complete agreement with Tesla on this matter, the issue of "the Martian signals" is still exploited by misguided cynics to ridicule Nikola Tesla today. Tragically, many of Tesla's severest critics are woefully unaware of his professional credentials, activities, and stature in the scientific and industrial communities of his day. We believe that there is a sound explanation for the incident. Conducting both an experimental and a theoretical analysis, we discussed Tesla's 1899 receivers in considerable detail in a paper presented at the 1994 Colorado Springs Symposium, and we believe that both the operation and limitations of his Colorado Springs receivers are now well understood. Unlike his Extra Coil resonator (which operated with an output of 12-18 MV in the region of 88 kHz to 100 kHz [Fig.2]), the RF detectors functioned primarily in the 8 kHz to 22 kHz range. Initially, one might suppose that no extraterrestrial signals could ever be detected in this spectral regime because the ionosphere is opaque at these frequencies. Analytically and experimentally, this is demonstrably not the case. Under the appropriate conditions there does indeed exist an ionospheric window in the lower VLF regime, and surprising results have been obtained with receivers reconstructed as described by Tesla in 1899.

§ 2. Some History.
Before we launch into a technical discussion of the "Martian signals", we would first like to recall Tesla's actual published reports of the summer night that he made the initial observations of what may be asserted as the original pioneering achievement in radio astronomy. He described the discovery as follows:"

"... Even now, at times, I can vividly recall the incident, and see my apparatus as though it were actually before me. My first observations positively terrified me, as there was present in them something mysterious, not to say supernatural, and I was alone in my laboratory at night..." [Fig. 3] The changes I noted were taking place periodically, and with such a clear suggestion of number and order that they were not traceable to any cause then known to me. I was familiar, of course, with such electrical disturbances as are produced by the sun, Aurora Borealis and earth currents, and I was sure as I could be of any fact that these variations were due to none of these causes ... It was sometime afterward when the thought flashed upon my mind that the disturbances I had observed might be due to an intelligent control. Although I could not decipher their meaning, it was impossible for me to think of them as having been entirely accidental. The feeling is constantly growing on me that I had been the first to hear the greeting of one planet to another. A purpose was behind these electrical signals; and it was with this conviction that I announced to the Red Cross Society [see above], when it asked me to identify one of the great possible achievements of the next hundred years, that it would probably be the confirmation and interpretation of this planetary challenge to us. Since my return to New York more urgent work has consumed all my attention; but I never cease to think of those experiences and of the observations made in Colorado. I am constantly endeavoring to improve and perfect my apparatus, and just as soon as practicable I shall again take up my investigations at the point where I have been forced to lay it down for a time ... Absolute certitude as to the receipt and interchange of messages would be reached as soon as we could respond with the number 'four,' say, in reply to the signal 'one, two, three.'"

To the informed mind of the early 20th century, however, the existence of a Kennelly-Heaviside layer precluded the possibility of radio astronomy and extraterrestrial radio communication. In his classic 1919 paper, G.N. Watson observed:

"A consequence of [the existence of an ionospheric shell surrounding the Earth] places grave obstacles in the way of communications with Mars or Venus, if the desirability of communications with those planets should ever arise."

While it is understood that certain high frequency propagation windows exist through the ionospheric envelop, it is still commonly thought, even today, that the transparency of the

"The sunspot cycle was a minimum in 1901, and the Zurich sunspot number was 10, or less, from 1898 to 1902. [See Fig. 4.2.]"
Fig. 3 Alone in my laboratory at night...
ionosphere is negligible at Tesla's frequencies of observation.  

[See Fig. 4.1] This misconception is not unequivocally correct. While it is possible that what Tesla heard was attributable to natural VLF phenomena, in this paper we will explore the possibility that the signals were extraterrestrial. In particular, we will explore the possibility that the radio signals heard by Tesla were actually of planetary origin.

§ 3. Transparency and Ionospheric Windows.

The radio exploration of the universe has been conducted primarily at frequencies from 6 MHz to 30 GHz. At lower frequencies, the ionosphere becomes dramatically opaque. At shorter wavelengths, the atmosphere selectively absorbs radiation in the millimeter, infrared and ultraviolet regions but possesses a remarkable window in the optical region that permits us to visibly look out into space and behold, as Milton has so eloquently expressed, "this fair moon and these the gems of Heaven, her starry train."

A variety of techniques have been examined in an effort to combat the problems of radio transmission through plasmas below the plasma frequency. One of the most interesting methods is to employ a small static magnetic field to open a 'spectral window' to permit wave propagation. Hodara has noted that,19

"The results are not new, as they stem from the classical Appleton-Hartree formula . . . [There exists] a window below the gyro frequency when a right-handed (RH) circularly polarized wave propagates in the direction of B, (longitudinal field). This mode of propagation is of interest since the location of the window is not dependent on the plasma resonant frequency. The window's location is determined solely by the strength of the static magnetic field independent of the electron density . . ."

These results led us to ponder the possibility that the Earth's magnetic field might open a radio astronomy window well below the ionospheric plasma frequency (f₀ ~ 3 Mhz).

§ 4. The Influence of a Superposed Magnetic Field.

Because of the presence of the Earth's magnetic field, the velocity of charged particles will not be parallel to the electric field vector of the incident wave, but will exhibit cyclotron oscillations about the B vector at a "gyrofrequency" given by

\[
\omega_{g} = 2\pi f_{g} = -\frac{qB_{z}}{m}
\]

The peak value of the Earth's magnetic induction is about 0.5×10⁻⁴ Tesla so, typically, the Earth's gyrofrequency is taken to be on the order of \(f_{g} = 1.4 \text{ MHz}\), which is somewhat below the 3 MHz plasma frequency of the ionosphere. It is common practice to define the following parameters relating to plasma frequency, gyrofrequency, and collision frequency:

\[
\chi(f) = \left(\frac{\omega_{g}}{\omega}\right)^{2}; \; \gamma(f) = \frac{\omega_{g}}{\omega}; \; \gamma(f) = \frac{\omega_{g}}{\omega}
\]

Further, one defines the normalized transverse and longitudinal gyrofrequencies

\[
Y_{l}(f) = Y_{l}(f) \sin(\xi) = -\frac{q_{B_{l}}}{m \omega}; \; \omega_{l} \omega
\]

\[
Y_{t}(f) = Y_{t}(f) \cos(\xi) = -\frac{q_{B_{t}}}{m \omega}; \; \omega_{t} \omega
\]

where \(\xi\) is the angle between the direction of the wave propagation and the magnetic field. Consequently \(B_{l}\) is the component of \(B\) along the direction of wave propagation, and \(B_{t}\) is the component of \(B\) transverse to the direction of the wave. The complex index of refraction for a magnetically biased plasma is easily expressed as

\[
\frac{n_{p}}{1} = \frac{\chi_{0}}{1 - \rho\chi_{0}} = \frac{r_{l0}^{2}}{2(1 - \rho\chi_{0})} + \frac{r_{t0}^{2}}{1 - \rho\chi_{0}}
\]

This is the famous Appleton-Hartree equation for a magnetically biased magneto-ionic medium.\(^{20,21}\) When the wave propagates parallel to the magnetic field the index of refraction will be real, and therefore wave propagation will be possible for frequencies below the plasma frequency for the right-handed polarized wave (which corresponds to the - sign) in the longitudinal case. The Appleton-Hartree equation for the index of refraction permits the calculation of ionospheric transparency in the magnetically biased case. The complex propagation factor is related to the complex index of refraction as

\[
\gamma(f) - \alpha(f) - j B(f) = j n(f) \frac{\omega}{c}
\]

and the propagation attenuation varies as \(e^{-\alpha f}\). Since \(\alpha\) varies with the electron density profile, the total absorption along a propagation path may be expressed in dB as

\[
A_{\text{tot}}(f) = 20 \log_{10} \int_{0}^{\infty} e^{-\alpha f} \omega dt = 8.686 \int_{0}^{\infty} \alpha(f, \nu) dt \text{ dB}
\]

This permits one to calculate and plot the ionospheric transparency. [See Fig. 5.4] The result specifically exhibits an Extraordinary wave VLF window for the kilometric wavelengths at which NASA now asserts that Jupiter and Saturn radiate sporadic signals toward the Earth. These are also the very frequencies to which Nikola Tesla's Colorado Springs receivers were tuned.

§ 5. Project LOFTI.

The presence of a magnetic field, such as that of the Earth's, will create a "window" for some band of frequencies below the plasma frequency. Fillipowsky and Muehldorf have noted that the idea of a terrestrial magnetically biased VLF window occurred to Navy scientists at NRL (the US Naval Research

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Figure 1. The electromagnetic spectrum showing relative transparency of the earth's atmosphere and ionosphere. (From Kraus, Radio Astronomy, 1st edition, 1966, p. 2.)

Figure 2. Plot of the Zurich smoothed sunspot numbers for 1850 to 1960. (From Kraus, Radio Astronomy, 1st edition, 1966, p. 325.)
Fig. 5.4 Night-time Extraordinary wave ionospheric transparency for frequencies from 1 Hz to 100 MHz during a solar minimum. (The horizontal scale is in kHz.) Note that even under the best of conditions the ionospheric transmissivity in the 200 kHz to 2 MHz region drops below -60 dB.
Laboratory), and experimental measurements were actually conducted at a frequency of 18 kHz, where VLF transmitting station NBA in the Panama Canal Zone served as a convenient RF source. A receiver and translator were mounted on a low orbiting satellite, which orbited just above the ionosphere, and the transparency of the ionosphere was measured during the time of a solar sunspot minimum. The experiment has been described as follows:  

"Earth's magnetic field and collisions make it possible to use VLF for satellite communications. An experiment conducted to test the feasibility of this concept showed good penetration of the ionosphere at 18 kHz.

In order to evaluate the attenuation, the Appleton-Hartree formula must be evaluated for longitudinal propagation. Under condition that \( N > 10^9 \) electrons/m\(^3\), \( v < 10^7 \) collisions per second, and \( f = 1 \) MHz, the attenuation for 18 kHz may be [calculated]. For the experiment an exact evaluation of the Appleton-Hartree equation was used. From this, the least possible cumulative attenuation for the ionosphere at 18 kHz was computed. The cumulative attenuation is a function of altitude. For 18 kHz the least cumulative attenuation at night is constant above 200 km and totals about 2 dB; during the daytime it is 28 dB above 200 km.

The experiment was implemented by launching the LOFTI - I satellite. The launch took place at Cape Canaveral on February 21, 1961. . . An 18 kHz signal was transmitted to the LOFTI satellite and the satellite receiver output was telemetered on a 136 MHz carrier back to Earth-based stations.

The results of this experiment reveal that a considerable portion of the VLF energy penetrates into the ionosphere. Most of the loss occurs at low altitudes (below 100 km). . . Evaluation of the measurements showed that, for the magnetic field component, the night-attenuation [at 18 kHz] is less than 13 dB and the day-attenuation is less than 38 dB, 50% of the time."

In spite of the fact that the details of the LOFTI (LOW Frequency Trans-Ionospheric) experiments are well documented, this information about the VLF ionospheric window is not common knowledge among radio astronomers, even today. Using conventional models for the concentration of electrons in the night and day ionosphere, from 50 km out to 1000 km, and for the electron collision frequency profile, the transparency of the ionosphere was measured during the time of a solar sunspot minimum. The experiment has been described as follows:  

"The signal intensity data so far reduced to statistical form indicates that 50% of the time the magnetic field intensity of the VLF wave is reduced less than 13 dB at night and less than 38 dB by day because of passage through the ionosphere. The corresponding figures for 10% and 90% of the time are 4 dB and 29 dB at night, and 33 dB and 45 dB by day. . . Satellite communication using VLF radio waves is feasible and affords some interesting possibilities for future applications."


No progress is to be made in resolving the "Martian" controversy without first possessing an understanding of the mode of operation of Tesla's receivers. Space does not permit an adequate discussion of Tesla's receiver architecture in this brief review. As part of a 1990's study of Tesla's 1899 lightning observations, we performed a fairly extensive investigation of Tesla's Colorado Springs receivers, and the reader is invited to turn to the latter for complete details. Tesla's receiver employed a coherer stressed to breakdown (avalanche), not by DC but rather by locally generated RF injected into the detector stage, for greater sensitivity. In the correspondence following Armstrong's 1917 regeneration paper, Carl Ort\(^2\) provided further insight, pointing out that he and his colleagues found that coherers could be made "very sensitive" by local oscillator RF injection.\(^2\)\(^8\)\(^9\) (This is not the superheterodyne principle.)\(^2\)

However, according to Ort's remarks the reason for the great gain was never understood until Armstrong's landmark regeneration investigation.\(^3\)

"Mr. Armstrong's experiments have shed new light on these phenomena and have indicated that the amplification obtained with a rectifying detector depends on the energy of the local oscillations which are applied to the detector, and that while the energy received is not magnified at all, the sensitiveness of the detector is increased. This increase is independent of the frequency of oscillation of the local source."

Ort continued his comments with a personal experience, that occurred in Austria in December of 1912, in which a remarkable gain was obtained from a simple detector.

"I investigated the phenomenon, applying sustained oscillations directly to the detector and found that the amplification was due to the increase of sensitiveness of the detector. Every... rectifying detector showed this characteristic. I found that the amplification could be obtained with any frequency not audible to the human ear. The limit of amplification was determined by the maximum impressed voltage of sustained RF at which the detector burned out. I was able to obtain amplifications of about 2000." [66 dB]

Again, we recognize Tesla's pioneering research and priority in this remarkable development of sensitive RF detection. Tesla took Branley's existing high impedance coherer element (with sensitivities on the order of 10 volts) and placed them at the high impedance end (the top) of his tuned resonators, which had voltage magnifications proportional to Q, and in so doing he increased the voltage sensitivity of the detector by a factor on the order of 100 (i.e., 40 dB). (It also gave the detector selectivity, which was something new.) He then injected a local...
Figure 6.

Minimum possible transmission loss (least possible attenuation) of an 18 kHz radio wave passing vertically upward through a standard model ionosphere versus altitude. (From Leiphart et al., 1962.)
oscillator RF voltage across the coherer (by tightly link coupling the local oscillator to the resonator) for the purpose of bringing the coherer's operating point near avalanche, to further increase the sensitivity another 66 dB. Tesla discovered a technique by which the nonlinear resistance of a coherer (as a function of injected locally generated RF) could be triggered and exploited by an exterior pulse signal. The receiver is not an envelope detector!! Having a weak signal initiate the process and using the resulting (voltage controlled) resistance decrease to regeneratively "ratchet up" the Local Oscillator RF, which further decreased the coherer resistance (repeating over and over) so that ultimately the relay would be triggered, gave Tesla an overall improvement of 106 dB in sensitivity over contemporary (1899) receiver technology - and an audio "Beep" each time the receiver is pulsed by an RF transient signal in the passband of its grounded helical resonator stage: the earphone response is a triggered tone at the coupled oscillator beat frequency. This response is not heard with a conventional receiver because envelope and synchronous demodulators do not give a triggered tone. They replicate the envelope of the RF pulses. Where Tesla's receivers give "Beeps", modern communications receiver respond with clicks and static.

Why have Tesla's receivers not enjoyed popularity in the engineering community? Why didn't Tesla continue his receiver research? Although extremely sensitive as RF indicators, Tesla's regenerative coherer detectors were not appropriate for envelope detection such as was required by the subsequent evolution of AM broadcasting and wireless communications. For this reason, the development of his receiver technology did not progress much beyond his early patents. Again, even by today's commercial standards, Tesla's receivers were more than adequate to detect the presence of RF signals in the 30 - 300 µV range. (Nothing this sensitive appeared until the advent of Armstrong's superregenerative detectors, which work right down to the thermal noise floor.) What set Tesla's limit is the terrestrial atmospheric noise field, not receiver sensitivity.

While it is true that lightning and atmospherics peak in this region, and Tesla certainly tracked electrical storms with his receivers (and, therefore, knew the distinction between atmospherics and the signals in question), one asks, "What might have been the physical origin of the sequential signals that gave the appearance of conveying intelligence at these kilometric wavelengths?"


Today it is known that both Saturn [Fig. 7] and Jupiter [Fig. 8] behave as powerful electromagnetic sources, transmitting average powers of 1 GW and 10 GW, respectively. The discovery of decametric radiation from Jupiter was first announced in 1955 by Burke and Franklin in 22 MHz where the ionosphere is readily transparent at night and for a substantial portion of the day. Actually, most shortwave listeners and amateur radio operators have heard the Jovian signals without grasping what they are hearing.

Recall that in his 1610 book, Message from the Stars (Sidereus Nuncius), Galileo (1564-1642) reported his discovery that Jupiter has 4 moons revolving about it, which he named Io, Europa, Gannymede, and Callisto. (No more Jovian moons were discovered for another 282 years!) John Milton (1608-1674) met Galileo in Florence in 1637 and refers to the Tuscan astronomer and his "optic tube" at least three times in Paradise Lost. There is a striking 1711 painting by the artist Donato Creti (1671-1749), which integrates a lavish pastoral landscape with the excitement of the new astronomy. It shows astronomers observing Jupiter in the evening sky, but Jupiter and its four moons are portrayed (magnified and inverted) as they would be seen through a Galilean telescope.

§ 7.1 Early Observations of Jupiter's HF Radiation.

The radiation, which originally was thought to come from localized regions on Jupiter and now seems to be associated with the planet's magnetic field configuration and the angular position of its satellite Io [Fig. 10], almost always has a duration of 2 hours or less and a period of variable activity that may last for several days. Describing the early reception of the decametric Jupiter signals at 27 MHz in the landmark special issue of the Proceedings of the IRE devoted to radio astronomy, Dr. Kraus of the Ohio State Radio Observatory has written, "The Jupiter signals are characterized by their impulsive or pulse-like nature, in many respects appearing similar to static from a terrestrial thunderstorm... The clicks may be of only a few milliseconds duration and may be single or multiple. The multiple clicks are usually double with an occasional triplet. The spacing between these multiple clicks is of the order of one-fourth second or less.

Professor Kraus' initial 1956 observations were actually performed at wavelengths of 10 to 15 meters using relatively modest conventional wire antennas, and his receiver consisted of an RF preamp ahead of a standard communications receiver. The existence of these doublet and triplet events puzzled Kraus, and he even went so far as to hypothesize that; "... the second and third pulses are echoes of the first. The triple pulse with approximately 0.3 second spacing is particularly significant in this connection since each succeeding pulse not only becomes smaller in amplitude, but more spread out in time."

We mention these multiple-impulse events because they are the very kind of signals which would initiate a 400 Hz "Beep-Beep-Beep" tone sequence in the earphones of Tesla's triggered receivers. The Reader may turn to the Appendix, which gives an overview of the Jupiter-Io system and how Jovian storm forecasts are presently performed.

§ 7.2. Cosmic Kilometric Radiation.

The Jovian kilometric flux density reaching the Earth has been estimated to be on the order of 10⁻¹⁷ Jy, i.e. 10⁻¹⁹ watts/m²/Hz. The VLF radiation was observed by Voyager 1 to be narrowband, physically centered near 200° CML III, and often came in individual bursts of less than 6 seconds duration (which was the shortest duration that the VLF receivers on Voyager 1 could measure). These would certainly be
Fig. 7 Saturn (Cronos), of the race of Titans, child of Earth and Heaven.
Fig. 8 Jupiter, son of Saturn, vanquisher of the Titans, father of gods and men, whose weapon was thunder. [Jupiter, Io, Europa (right), and Callisto (lower middle).]
consistent with Tesla’s observations. It has been suggested that the Jovian kilometric radio source is probably a localized region of the high density plasma torus encircling Jupiter near the orbit of Io.37

While others have suggested that Tesla’s observations might somehow be linked to Jovian radiation, it has always been a mystery to us how such fields generated at 22 MHz (and detected in 1955 with modern communication receivers) could ever be related to fields at the frequencies that Tesla used (5 to 20 kHz), or how these VLF fields could ever have penetrated the ionosphere. However, it is now known that Jupiter and Saturn radiate RCP waves in the kilometric range, as well as in the decametric range discovered in the 1950’s. That is, these planets appear to be sources of kilometric radiation at the very frequencies where Tesla’s receivers were the most sensitive, and where a VLF ionospheric radio astronomy window exists during a solar minimum.


Software predictions don’t have to run forward in time only. They can be used to predict the past. Using The American Ephemeris and Nautical Almanac39 for 1899, several software packages for predicting Jovian radio storms, and conventional desktop planetarium software, we have examined the correlation of Jovian emissions and the night-time skies as observed from Colorado Springs during the summer of 1899.

1899-1901 was a time of solar minimum and not only was the MUF considerably reduced, but the ionospheric transparency for RCP kilometric waves was about as good as it gets. Tesla reported that he started his atmospheric storm electrical observations in mid-June of 1899 (when both Mars and Jupiter set late at night), so our search for correlated Jovian storms begins in mid-June. By December of 1899, both Jupiter and Mars set late in the afternoon. We have selected five possible events occurring over the summer of 1899 that might lead an observer to conclude that Mars was intermittently transmitting signals to the Earth and, because we are constrained by publication room, we will comment on only one evening in July. What we looked for was an answer to the question, "Is there any correlation of the cessation of the Jovian signals with the disappearance of Mars below the horizon?" (This would give the appearance of radio signals from Mars.)

§ 8.1. The Io Events of July 22, 1899.

There is an interesting coincidence between the termination of several predicted Jovian events and the disappearance of Mars on the western horizon on the night of July 21, 1899. The Ephemeris gives the Martian set time as 05:45 GMT July 22, 1899 (9:44 PM on July 21, 1899 local standard time) at an azimuth of almost 270° exactly. Such a time would appear to meet Tesla’s remark that he heard the signals when "alone in my laboratory at night" and "in the summer of 1899". The Martian set time is given for an unobstructed sky. Mars would actually disappear earlier than 9:44 PM because of the high mountains to the west of Colorado Springs. Tesla’s laboratory (at the intersection of Kiowa and Foote Streets) was at an elevation of 6060 feet. At an azimuth of 270° the mountains rise to an elevation of 10,245 feet at a distance of 6.67 miles from the laboratory. This would give Tesla’s laboratory site a western visual horizon at an elevation angle of 6.78°. [See Fig. 11(15).] Noting this visual western horizon, Mars drops below the western mountains at 9:05 PM local standard time. [See Figure 12(16).] Is there any correlation of Mars’ set time with the cessation of radio signals from Jupiter? [See Fig. 13(17).]

There is a dramatic double-event correlation on this night. An Io-A event is predicted to occur between 02:56 - 03:55 GMT July 22, 1899 (7:56 to 8:55 PM July 21, 1899 local standard time). That is, the Jovian Io-A signals are predicted to cease about 10 minutes prior to Mars’ disappearance below the visual horizon in the western sky. Furthermore, there is a Non-Io event predicted to occur between 02:47 - 0:4:12 GMT (7:47 to 9:12 PM July 21, 1899 local standard time). This Jovian event is predicted to cease 7 minutes after Mars sets. (Interestingly, the criteria employed in "Radio Jupiter 2.0" software package predicts that both the Io-A and the non-Io-A events cease at exactly 9:00 PM local standard time, i.e. 5 minutes prior to the disappearance of Mars below the western horizon.) Again, to an alert observer, it would not appear unreasonable to associate the radio signals with the planet Mars, which was just disappearing below the western visual horizon at the very time that the radio signals ceased. This event would seem to strongly correlate with Tesla’s description of his discovery of cosmic radio waves. Two days later, Tesla’s diary gives a fairly thorough documentation of the construction and performance of his coherers.

We believe that there is a remarkable correlation of Martian set times with the predicted cessation of radio signals from Jupiter. (With some imagination, it might even have been construed that Mars was broadcasting to cities on the longitude of Colorado Springs, where Tesla’s transmitting station was located!) To an alert observer, it would not have appeared unreasonable to associate the radio signals with the planet Mars.

§ 8.2. Jovian Radiation Events Predicted for 1899.

From our analyses, we conclude that there were at least five occasions that could possibly fit Tesla’s description of his detection of extraterrestrial radiation. (These are summarized in Table I below.) And, all of these would clearly point to the planet Mars as a probable source. What we infer is the apparent concurrence and cessation of Jovian radiation pulses with the position of Mars as it set on the horizon. At the time of the first five examples Mercury, Venus and the Sun were below the horizon, so they could readily be eliminated as the source of the sequential pulses (as Tesla noted). This would leave Mars, Jupiter and Saturn as possible sources. The cessation of reception as Mars passed below the horizon, with Jupiter and Saturn still in the sky, would appear to eliminate those major planets, again suggesting that Mars was the probable source. Since the signals were not correlated with the weather, which produced an entirely different type of signal in Tesla’s receivers (see our discussion of Tesla’s weather-related observations38), and since the research was performed during a solar minimum, it would seem admissible to eliminate the aurora as the source
Date: July 21, 1899  
Latt: 38:50:06  
Long: 104:48:01

Figure 11. Predicted decametric radio radiation from Jupiter for July 22, 1899 (GMT) and local ephemeris. The upper time-bar reads GMT and the lower reads local standard time. Midnight is at 07:00 GMT. Note the Non-Io-A event occurring between 7:47 and 9:12 PM local time. There is also an Io-A event occurring between 7:56 and 8:55 PM. Mars dips below the local horizon (6.78 deg.) at 9:05 PM.
Fig. 12  An Azimuth-Elevation plot of the western sky at 9:05 PM on July 21, 1899 (local time). Stars to magnitude 3 are shown. Mars is at an elevation of 6.78°, i.e. right at the visual horizon as viewed from the site of Tesla's research station.
Fig. 13  The planetary configuration of July 21, 1899. Note that the Earth has passed Mars, which now sets before Jupiter.
of these signals that conveyed the notion of intelligent communication. Return to 1899 and ask yourself, "What is left?" (At VLF, certainly not Marconi in the English Channel!)

Finally, we call attention to the fact that although these astronomical predictions provide support for Tesla's assertions, we think that the strongest argument in his favor is that there is a demonstrable ionospheric window at the very frequencies where his receivers functioned and kilometric radiation is now known to be emitted sporadically by Jupiter and Saturn.

§ 9. What Would You Have Done?

Before you answer that question, consider the time frame in which Nikola Tesla (1856-1943) labored. He arrived at Colorado Springs in May of 1899. (He had been there previously, conducting experiments on Pike's Peak in 1896.) During June and July the western panorama visible in the late evening hours from the laboratory's double doors was presided over in the southwest by Mars, Arcturus and blue-white Spica, while Jupiter and red giant Antares were almost directly on the meridian, and the bright first magnitude stars Deneb, Altair and Vega were raining their own celestial fire as they, and the Milky Way, rose in the East. In the warm evening air, clearly, the enchanting spell of the brilliant starry sky.

Tesla reports that he started receiving atmospheric static in mid-June with his receivers. (From his notes it is evident that his sensitive regenerative receiver designs continued to evolve from mid-June to late September.) Put yourself in Tesla's place. There were no wireless stations on our planet other than his own (certainly none operating in the 10 kHz range where his receivers were tuned). His receivers were detecting code-like bursts which appeared only at certain times that were uncorrelated with diurnal variations, and they occurred only while Mars (and Jupiter and Saturn) appeared in the visible sky. We think that we've documented that the kilometric signals from Jupiter could have terminated when Mars was just passing below the curtain of mountains viewed on the western horizon from Tesla's laboratory.

In 1902, Lord Kelvin (1824-1907), himself a believer in the Martian signals, proclaimed that he was in complete agreement with Tesla on this issue. Oliver Lodge (1851-1940) was then attempting to detect RF solar emissions but he was listening at the wrong frequencies and with detectors far too insensitive. Twenty years later, Guglielmo Marconi (1874-1937) claimed that he, too, had heard the signals from Mars. [Marconi and Kelvin never drew the ridicule and resentment for their remarks that Tesla received.] Tesla's assessment was that Marconi had heard RFI: Marconi's receiver was merely responding to transmitter "undertones." Ever a focal point of mystery and speculation, even Jonathan Swift's fictional masterpiece puzzles us. In 1726 he not only tells us that Mars has two satellites, but also that their periods are 10 hours and 21.5 hours. Remarkably, Mars' two moons, Phobos ("fear") and Deimos ("panic"), were not discovered until 1877, and with periods determined as 7.65 hours and 30.28 hours, respectively. It was also in 1877 that Schiaparelli first

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* Unlike Marconi, whose 1919 receivers performed in the LF/MF region, undertone reception would not have been the case for Tesla's Colorado Springs 10 kHz observations: undertones (subharmonic beats) require the presence of strong local transmitter signals (which Tesla did not have to contend with in 1899) and nonlinear mixing. Furthermore, VLF undertones are not radiated by antennas whose lengths are short relative to the wavelength, so there would have been no 1899 VLF signals emanating from the English Channel capable of being received in Colorado Springs, as some have mistakenly asserted.

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### TABLE I. SUMMARY OF SELECTED JOVIAN STORM PREDICTIONS

<table>
<thead>
<tr>
<th>DATE (Local)</th>
<th>Storm Type</th>
<th>Predicted Cease (Rad-Jup 1.0)*</th>
<th>Predicted Cease (Rad-Jup 2.0)**</th>
<th>Mars Sets (Local Time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 22, 1899</td>
<td>Non-Io-A</td>
<td>10:22 PM ✓</td>
<td>10:20 PM ✓</td>
<td>10:22 PM</td>
</tr>
<tr>
<td>July 1, 1899</td>
<td>Io-D</td>
<td>10:31 PM ✓</td>
<td>10:00 PM ✓</td>
<td>10:00 PM</td>
</tr>
<tr>
<td></td>
<td>Io-B</td>
<td>9:34 PM ✓</td>
<td>9:40 PM ✓</td>
<td>10:00 PM</td>
</tr>
<tr>
<td>July 7, 1899</td>
<td>Io-C</td>
<td>9:45 PM ✓</td>
<td>9:40 PM ✓</td>
<td>9:43 PM</td>
</tr>
<tr>
<td>July 17, 1899</td>
<td>Io-D</td>
<td>10:10 PM ✓</td>
<td>9:00 PM ✓</td>
<td>9:18 PM</td>
</tr>
<tr>
<td>July 21, 1899</td>
<td>Io-A</td>
<td>8:55 PM ✓</td>
<td>9:00 PM ✓</td>
<td>9:05 PM</td>
</tr>
<tr>
<td></td>
<td>Non-Io-A</td>
<td>9:12 PM ✓</td>
<td>9:00 PM ✓</td>
<td>9:05 PM</td>
</tr>
</tbody>
</table>


The ✓ mark indicates a strong correlation between the cessation of a predicted storm and the setting of Mars.
observed the controversial "canali".

In 1883, Simon Newcomb (1835-1909), then director of the American Nautical Almanac, wrote the following:

"The early telescopic observers noticed that the disk of Mars did not appear uniform in color and brightness, but had a variegated aspect. . . The most interesting result of these markings on Mars is the probability that its surface is diversified by land and water, covered by an atmosphere, and altogether very similar to the surface of the earth. Some portions of the surface are of a decided red color, and thus give rise to the well-known fiery aspect of the planet. Other parts are of a greenish hue, and are therefore supposed to be seas. The most striking features are two brilliant white regions, one lying around each pole of the planet. It has been supposed that this appearance is due to immense masses of snow and ice surrounding the poles. If this were so, it would indicate that the processes of evaporation, cloud formation, and condensation of vapor into rain and snow go on at the surface of Mars as at the surface of the earth."

It was Harvard Observatory's William Pickering who first reported seeing dark spots where the Martian "canals" intersected. Astronomer Percival Lowell (1855-1914), on whose 1905 calculations Pluto was discovered by Clyde Tombaugh in 1930, described his contemporaneous optical observations of Mars in the most vivid of terms in his 1895 book, Mars. Through the 18" and 24" refracting telescopes at Lowell Observatory in Flagstaff, Arizona [Fig. 14] Mars appeared to Lowell as "a shimmering orange ball" with white polar caps and a system of dark green lines configured "like a spider's web" across the planet [Fig 15]. Three years later, fantasy writer, H.G. Wells was inspired to pen the Martian invasion story, "War of the Worlds" (1898), and later, "Star Begotten".

Tesla, in his 1907 article for Harvard Illustrated Magazine, acknowledged the strong predilection toward Mars that Lowell's work had contributed to his own conclusions:

"Chief among the stimulating influences was the revelatory work of Percival Lowell, described in a volume with which the observatory bearing his name has honored me."

Is it unreasonable to assume, as Tesla did, that the reception of "one - two - three" from an apparently identifiable extraterrestrial radio source could originate from some center of intelligence? Tesla interpreted the systematic sequence of pulses as an attempt to communicate intelligence through the universal concept of numbers. Interestingly, modern professional astronomers involved with the SETI (Search for Extra-Terrestrial Intelligence) program have embraced the identical concept. Concerning the search for extra-terrestrial intelligence funded at the Ohio State Radio Observatory, Professor Kraus writes:

"Our Big Ear was now listening for other-men on other planets circling other stars who might have built beacon stations to announce their presence... We are searching for some kind of narrow-band signal that would appear... If, in addition, it turned off and on in some systematic way this would be suggestive of an intelligent origin... Suppose we do detect a beacon signal? How could it be possible to understand the other-men about whom we know absolutely nothing? Is there anything that we and the dwellers on another planet even have in common? Is there any common semantic frame of reference?... The idea of numbers or counting would be common. We might suppose that the other-men could initiate their beacon transmission with a series of dots:

- - - - - - - etc.

The very narrow-band beacon signal would have alerted us to their presence and their slow dots and dashes taught us a language with which to understand them."

So, after a century of scientific progress, Tesla's speculations concerning a "Lingua Cosmica" have come to possess some degree of formal credibility in academic circles.

§ 10. What Really Happened?

It is now clear that Tesla's receivers can easily be stimulated by kilometric singlet, doublet, and triplet events (which occur quite frequently). Because of the 400 Hz beat frequency inherent in this receiver's coupled oscillation transformer, the 400 Hz audio response at the earphones (which re-initiates every time the receiver is stimulated) sounds like "Beep-Beep-Beep". For those of us that have heard the phenomenon, it is perfectly logical to describe the sound exactly as Tesla did on Orthodox Christmas of 1900 (January 7, 1900): "one... two... three...". [Would you like to hear a recorded response of a Tesla VLF receiver? Audio recordings were made at the Tesla receiver earphone during Jovian storms in the late Spring of 1996 (a solar minimum), and played at the 1996 ITS Symposium. A short audio clip, recorded from a Tesla receiver, has been inserted, here. Listen closely. A faint sequence of code-like pulses can be heard through the static. ("I could not interpret the signals, but they seemed to suggest a numerical code..." Tesla, 1935) You must agree that, whatever the mechanism, a numerical sequence clearly suggests itself to the listener. These are not inherent in the receiver, nor are they present at all times. (Incidentally, the Tesla receiver response during an electrical storm can be heard by clicking here.)

We conclude that the observations of Percival Lowell and his assertions concerning the possibility of life on Mars, the nearness of the red planet (Mars was in opposition on Jan. 20, 1899), the night-time signals when Venus and the sun were below the horizon, the coincidence of the cessation of the radio signals as Mars disappeared below the observational horizon at Tesla' laboratory, the apparent implication of intelligence in the signals, etc., all provided supporting evidence for Tesla to subsequently mistakenly ascribe the signals to the red planet rather than some other cosmic source. Dr. Kraus and the Ohio State Radio Observatory, in a remarkably similar example of mistaken identity, reported receiving distinct separated pulses from Venus in 1956:

"While monitoring for radiation from Venus, I also heard signals that came in distinct separated pulses. They seemed to be strongest when Venus was in the beam and seemed to follow Venus across the sky. I wrote a brief note about them published in Nature and suggested that they might come from Venus. It
Fig. 15 "like a spider's web..."
was a blunder, which taught me a lesson... It was something that has happened to other astronomers, physicists and chemists, including Nobel laureates, and continues to happen . . . When you dare to publish a new scientific observation or calculation ... you don't want to be found in error but you can be so cautious that you never publish."

Enchanting Urania, inspirational Muse and nymph-goddess of Astronomy, seems to playfully practice innocent deception on her most impassioned suitors: sic itur ad astra. ("Such is the way to the stars.")


Certainly, not everyone will agree with us. There may be other acceptable explanations. But, it is our opinion that it is entirely within reason to identify Tesla's signals as the detection of intense kilometric (VLF) emissions originating from Jupiter. Considerable work still needs to be done to convince the skeptical. However, the bottom line is that when you listen to the kilometric signals from Jupiter with one of Tesla's Colorado Springs receivers you occasionally hear "Beep... Beep-Beep... Beep-Beep-Beep!" Furthermore, extraterrestrial right circularly polarized kilometric signals penetrate the Earth's ionosphere during the time of sunspot minima. Tesla was at the right place, at the right time, doing the right thing, with the right equipment to be able to detect these unusual electrical signals of planetary origin. It was the scientific community that was unprepared.

In the early 1930s Karl G. Jansky (1905-1950) [Fig. 16], like Nikola Tesla before him, had been monitoring electrical disturbances due to thunderstorms. Using a vertically polarized rotatable modified Bruce array, he noted three distinct types of static at 20 MHz: that from local thunderstorms, that from distant thunderstorms, and "a steady hiss static, the origin of which is not known." Jansky was able to identify the latter as coming from the Milky Way50 [Fig. 17] and for this he has been popularly recognized as the "father of radio astronomy". Concerning cosmic radio signals, Tesla wrote in 1921:51

"Others may scoff at this suggestion or treat it as a practical joke, but I have been in deep earnest about it ever since I made the first observations at my wireless plant in Colorado from 1899 to 1900. . . . At the time I carried on those investigations there existed no other wireless plant on the globe other than mine, at least none that could produce a disturbance perceptible in a radius more than a few miles."

Tesla's pre-1900 radio astronomical observations haunted him the rest of his life, and he expressed a great desire to follow up on his remarkable discovery. In 1919 (fourteen years before Jansky's landmark paper), Tesla said:52

"In later years, I have bitterly regretted that I yielded to the excitement of ideas and pressure of business instead of concentrating all my energies on that investigation."

In an unpublished 1935 interview, at age 79, Tesla said:53

"Some of my discoveries and inventions have made electric history. They were practical devices, susceptible of commercial exploitation."

[The discoveries were the rotating magnetic field and coupled tuned RF systems. The inventions for which he holds legal priority include the AC motor and generator, the AC polyphase power distribution system, and radio communications. Consider NASA's awesome 2002 photograph14, "Earth at Night". [Fig.18] (What a breath-taking tribute to the genius and achievements of Nikola Tesla!) Can the reader identify even one pinpoint of light, anywhere in the photo, not operated through the electrical system given birth by Tesla? (And, the photograph only shows the optical spectrum - it reveals neither electromechanical applications nor radiowave communications.) Is there even one Noble Laureate since then that can be named who has contributed so much to relieve toil, dispel gloom and darkness, and harness the forces of nature for the benefit of humanity?]

Tesla continues, "... but my chief recreation was to study the universe, and the place of the earth in the starry system... [a method of communicating with other planets] ... I would willingly sacrifice all my other achievements to realize this dream."

This is the tragic story of a scientist that had to formulate theories and then devise his own hand-made sensitive instruments to delicately explore the enchanting wonders of the physical universe [Fig. 19], - authentic wonders that previously went undetected and existed only within the visions and dreams of his own creative mind. - electrical wonders and visions that few scientists would be able to perceive or comprehend until generations after their discovery was declared before a community of visionless skeptics. Not since the time of Leonardo da Vinci (1452-1519) has the world witnessed the energy, insight and achievements of such a gifted thinker and versatile genius. In an eloquent moment of reflection, Neils Bohr once said, "With deepest admiration, we think of how Tesla could accomplish such great achievements ..."

We hope that this little study will raise legitimate interest and elevate the controversy surrounding Tesla's "Martian signals" to quantifiable terms. Certainly, he was the first to detect, observe and study natural VLF radio waves from atmospheric storms. It is our conclusion that, under extremely favorable (but entirely feasible) circumstances, Tesla could have also heard the audio reaction of his regenerative detectors responding to the impulsive kilometric noise emanating from the planet Jupiter.

APPENDIX I. Radio Signals of Planetary Origin.

In this brief Appendix, we want to provide a concise introduction to the issues and concepts employed in the prediction of the non-thermal Jovian signals for 1899.

1. A Description of the Jovian System.

Jupiter is encircled by a system of light and dark bands of clouds parallel to its equator, which rotate differentially. Since no physical surface features can be used for reference purposes two coordinate standards have been adopted for Jupiter: System I has the rotational period of 09h 50m 30s corresponding to the Equatorial band of clouds, and System II moves a little slower.
Fig. 16  Karl G. Jansky (early 1930's)
Fig. 17. Jansky identified the static as coming from the Milky Way.
Fig. 18 Tesla's Tribute - "Earth At Night". [For a larger version, go to, http://antwrp.gsfc.nasa.gov/apod/image/0208/earthlights02_dmsp_big.jpg]
with the rotational period of 09h 55m 40.6s corresponding to the rotational period of the mid-latitude (temperate zone) clouds.

(a) CML III.

Jupiter's magnetic poles are tilted about 10° relative to its axis of rotation and, with the advent of radio observations, it was found that the planet's magnetic field, which appears to have a rotational period of 09h 55m 29.710s, could provide a coordinate reference system attached to the planet's surface.\(^5\)

The corresponding angular speed of a longitudinal line attached to the planet is 99.249 sec/deg. The International Astronomical Union subsequently designated this reference frame as System III. The Sub-Earth longitude or Central Meridian Longitude (denoted as CML III) of the system rotating with the above period coincides with the System II longitude facing the Earth at 0h Universal Time on January 1, 1965. Such a system of coordinates permits the specification of various features in Jupiter's magnetic field as they rotate with the planet. James Sky has noted that,\(^5\)

"It became apparent when plotting radio emission occurrences vs. CML III that the probability of detecting a radio event is greatly enhanced when any of three particular longitudes turns to face the Earth. These areas of enhanced probability have been named regions A, B, and C... region A, which peaks around 260° CML III, is the region of highest correlation. Regions B and C, at about 170° and 320° respectively, are somewhat less reliable, but certainly distinct and important predictors."

In addition to the Central Meridian Longitude of the planet, a correlation was also found with the angular position of one of Jupiter's moons.

(b) SGC: The Io Phase.

From a catalogue of Jovian radio observations made between 1961 and 1963, E.K. Bigg deduced in 1964 that Jupiter's inner satellite, Io, appears to control the decametric emissions, which reach the Earth, to a remarkable degree.\(^5\)

[See Figure 20-I.1. The dependence of Jupiter's decametric radio signal strength on the angular position of the satellite Io.]

This figure, taken from Bigg, shows that there is a great probability of Jovian radiation whenever Io approaches two angular positions: 93° and 246° after Io's Superior Geocentric Conjunction (SGC). [The Superior Geocentric Conjunction is that position of Io when it is directly on the far side of Jupiter when Jupiter and Io lie in a straight line to the Earth. The Io phase, or SGC angle, is measured from that reference orientation as Io revolves around Jupiter. (See Figure 21-L3.)] Io has a mean period of 2,548.5 minutes and moves angularly at 424.75 sec/deg.


Realizing that both the CML III and Io's angular position relative to the SGC correlate with radio emissions from Jupiter, Bigg plotted the intensity of the radiation on a graph with the SGC angle as ordinate and the CML III as abscissa.

[See Figure 20-I.2. This is a sketch of radio signal strength on a plot of the Io phase (Io's angular position with respect to the SGC) versus the rotational orientation of Jupiter (the angle between Jupiter's CML III and an Earth-Jupiter reference line).]

A procedure for the prediction of decametric radiation from Jupiter was then readily deduced. The Figure clearly reveals patterns where a high probability of signal reception exists. These configurations of activity may be summarized as shown in Table II:

<table>
<thead>
<tr>
<th>STORM</th>
<th>CML III</th>
<th>SGC</th>
<th>CHARACTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Io-A</td>
<td>200°-270°</td>
<td>205°-260°</td>
<td>RH polarized L Bursts</td>
</tr>
<tr>
<td>Io-B</td>
<td>105°-185°</td>
<td>80°-110°</td>
<td>RH polarized S Bursts</td>
</tr>
<tr>
<td>Io-C</td>
<td>285°-370°</td>
<td>225°-260°</td>
<td>LH polarized L &amp; S Bursts</td>
</tr>
<tr>
<td>Io-D</td>
<td>100°-200°</td>
<td>95°-130°</td>
<td></td>
</tr>
<tr>
<td>Non-Io-A</td>
<td>200°-280°</td>
<td>0°-360°</td>
<td></td>
</tr>
</tbody>
</table>

The CML III regions on the plot can be defined as shown in Table III:

<table>
<thead>
<tr>
<th>REGION</th>
<th>CML III</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>200° - 290°</td>
</tr>
<tr>
<td>B</td>
<td>100° - 200°</td>
</tr>
<tr>
<td>C</td>
<td>290° - 320°</td>
</tr>
<tr>
<td>D</td>
<td>20° - 100°</td>
</tr>
</tbody>
</table>

Figures I.1 and I.2 reveal that two phenomena are actually occurring. Clearly, the radio signal strength depends upon the departure of Io from the superior geocentric conjunction: Io strongly influences the emission of radio signals from Jupiter. But it is also apparent that the angular orientation of Jupiter's magnetic poles relative to the Earth also govern the radiation we receive. Jupiter's magnetic poles are tilted slightly with respect to its axis of rotation and so, as Jupiter's Central Meridian Longitude rotates, the changing aspect of Jupiter's magnetic equator as viewed from the Earth causes variations in the observed field strength and polarization. Moore observes that,\(^5\)

"The total intensity goes through two maxima and two minima per revolution, the maxima occurring when the magnetic equator..."
Fig. 20-1.1  

Fig. 20-1.2  
This is a sketch of radio signal strength on a plot of the Io phase (Io's angular position with respect to the SGC) versus the rotational orientation of Jupiter (the angle between Jupiter's CML III and an Earth-Jupiter reference line). (Nature, Vol. 203, p. 1009.)
Fig. 21 I.3: This sketch illustrates the SGC (Superior Geocentric Conjunction), the Io phase, and also the CML (Central Meridian Longitude) of Jupiter on Jan. 1, 1965 at 0h GMT.

Fig. 21 I.4: This sketch illustrates the toroidal shaped plasma distribution around Jupiter and the orbit of Jupiter's moon, Io. The toroid is slightly inclined relative to Io's orbit because of the influence of Jupiter's strong magnetic field on the charged particles. The flux tube shown linking Jupiter and Io carries a current of about 5 million amperes.
is viewed edge on, and the minima when the equatorial plane is viewed from extreme positive and negative latitudes."

There is another phenomenon which comes into play for determining the variation of the Jupiter signals on Earth. The observed width of the Jovian radiation pattern is fairly narrow (on the order of 6°). Furthermore, Jupiter's orbit is slightly tilted with respect to the ecliptic plane (the plane of the Earth's orbit around the sun). To view it another way, from Jupiter's position, the plane of the Earth's orbit tilts slightly above and below Jupiter's orbital plane as the Earth revolves about the sun. The inclination is about 3.3° and this "Jovicentric Declination of the Earth" (D_E) moves the Earth into and slightly back out of the beam of radiation emanating from Jupiter. As a result, the probability of radio reception varies with D_E.

While the above observations imply a procedure for predicting when the Earth receives radio signals from Jupiter, they do not yet explain the physics of why the Jovian system should radiate at all. We will turn to that topic next.


It is now known that both Jupiter and Saturn possess substantial magnetic fields: B = 1 × 10^4 Tesla (tipped about 10° with respect to the axis of rotation) for Jupiter and B = 2.5 × 10^5 Tesla (tipped less than 1° with respect to the axis of rotation) for Saturn. (By way of comparison, the Earth's magnetic field is about 3 × 10^4 Tesla.) It is also known that these planets radiate nonthermal emissions at various wavelengths corresponding to frequencies extending from 3 kHz up to about 30 MHz.

While there exist a vast collection of hypotheses for the radiation from Jupiter and Saturn, it appears that the radio emissions are linked to electrical charges accelerated through the planets' magnetic field structure. Gyro radiation is produced when electrons spiral about magnetic fields under the influence of the Lorentz force at relatively low velocities. The frequency of the gyro radiation is given by

\[ f_g = \frac{eB}{2\pi m} - 2.8 \times 10^{10} B \]

Radiation from Jupiter at 22 MHz by this mechanism would seem to imply emission from a magnetospheric region where B ~ 7.86 gauss (1 Tesla = 1 Weber/m² = 10⁴ Gauss), while radiation at 10 kHz would seem to imply emission from a magnetospheric region where B ~ 3.57 milligauss. However, a simple application of conventional gyro radiation theory does not seem to explain the Jovian radiation spectrum. As pointed out above, it has long been recognized that the position of Io and its orbit plays some role in explaining Jovian radiation.

Io has a diameter of 3640 km and orbits Jupiter at a distance of 5.9 R_J (421.6 Mm; the equatorial radius of Jupiter is R_J = 71,398 km, and Jupiter's mass is M_J = 1.901 × 10²⁷ kg.), well within Jupiter's magnetosphere, with a period of 1.769 days. It has an atmosphere and at least seven active volcanoes, with plumes extending up to 250 km above the surface of the Jovian satellite.

Apparently, due to the sputtering action of material ejected from Io and high energy particles bombarding this moon, a toroidal ring of charged plasma particles has been created around Jupiter at the radius of Io's orbit. The "plasma torus" is slightly inclined to the orbit of Io due to the presence of Jupiter's strong magnetic field. (See Figure 21-L.4.) The kilometric radiation detected by Voyager 1 appeared to have been generated by plasma oscillations in the Io plasma torus.

It has been hypothesized that the Io-Jupiter system forms an enormous electrical generator. The Jovian magnetic field at Io is about 1900 nT and the motion of Io through Jupiter's magnetic field induces a \( \mathbf{v} \times \mathbf{B} \) voltage across Io of about 400 kV. As a result, plasma electrons are driven along Jupiter's magnetic field lines forming a "flux tube" that connects Io and Jupiter's conducting ionosphere. The current flowing between Jupiter and Io along this flux tube is in excess of 5 million amperes, and this gravitationally driven natural electrical generator (which would excite the enthusiasm of any electrical engineer) has been estimated to operate at a power level in excess of 10¹² watts. There are many other issues associated with radio emissions from Jupiter and Saturn, and the reader is invited to turn to the literature of radio astronomy.

Technical issues related to the construction of Tesla's receivers, the parameters associated with the operation of his facility as a VLF radio telescope, atmospheric noise fields, and further detectable radio emission events are treated in greater detail in the engineering report mentioned at the beginning of this paper. Karl Jansky probably detected decametric radiation from Jupiter, although that can't be documented. Again, it is our conclusion that, under extremely favorable (but entirely feasible) circumstances, Tesla could have readily heard the audio reaction of his regenerative peak detectors responding to the impulsive kilometric noise emanating from the planet Jupiter [Fig. 22].

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Fig. 22  Jovian system (in order): Io, Europa, Gannymede, and Callisto.
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TESLA SEES EVIDENCE RADIO AND LIGHT ARE SOUND

Nikola Tesla, Pointing to 'Grevious Errors' of the Past, Explains Radio as He Sees It at Age of 77 - He Expects Television

By Orrin E. Dunlap, Jr.

A tall, lean inventor in a cutaway walked into his skyscraper parlor thirty-three floors 'above the sidewalks of New York, laid his black derby on the table, opened the window and then was ready to talk about radio's past, present and future. He was Nikola Tesla, the inventor whose discovery of the rotary magnetic field made possible the alternating current motor. He described a system of wireless transmission of energy in 1892.

Seven milestones beyond three-score and ten, this electrical wizard, who came to America in 1884, looked back across the years, recalled where theorists often chose wrong paths at the crossroads of science and then turned his thoughts to the future in which television lurks.

A Spectacle That Frightens.

"There is something frightening about the universe when we consider that only our senses of sound and sight make it beautiful," said Mr. Tesla as his furrowed brow indicated he is puzzled with its destiny. "Just think, the universe is darker than the darkest ink; colder than the coldest ice and more silent than a silent tomb with all the bodies rushing through it at terrific speeds. What an awe-inspiring picture, isn't it? Yet it is our brain that gives merely a physical impression. Sight and sound are the only avenues through which we can perceive it all. Often I have wondered if there is a third sense which we have failed to discover. I'm afraid not," he said after some hesitation in thought.

Looking back to the mauve decade, to the turn of the century when the world was being thrilled with new ideas and discoveries, Mr. Tesla observes a vast change in the art of invention. Man, he finds, in this streamlined era of speed, has little chance to think.

Fruits of Seclusion

The big, modern research laboratories are but the incubators of ideas as he has watched them function. Seldom, if ever, he explains, has an original idea of consequence been born in an elaborate laboratory. The egg of science is laid in the nest of solitude. True, it may later be incubated, hatched and nursed in the million dollar laboratory.

"It is providential that the youth or man of inventive mind is not 'blessed' with a million dollars," said Mr. Tesla. "He would find it difficult to think. The mind is sharper and keener in seclusion and uninterrupted solitude. No big laboratory is needed in which to think. Originality thrives in seclusion free of outside influences beating upon us to cripple the creative mind. Be alone, that is the secret of invention; be alone, that is when ideas are born. That is why many of the earthly miracles have had their genesis in humble surroundings."

Radio experimenters of this age are following ancient theories, Mr. Tesla believes, and he warns that progress will be more rapid when they discard the old and adopt the new
ideas. His directions for getting on the right track of radio, television and sundry other branches of science follow:

"The fascination of the electro-magnetic theory of light, advanced by Maxwell and subsequently experimentally investigated by Hertz, was so great that even now, although controverted, the scientific minds are under its sway. This theory supposed the existence of a medium which was solid, yet permitted bodies to pass through it without resistance; tenuous beyond conception, and yet, according to our conceptions of mechanical principles and ages of experience, such a medium was absolutely impossible. Nevertheless, light was considered essentially a phenomenon bound up in that kind of a medium; namely, one capable of transmitting transverse vibrations, like a solid.

A Question Tesla Asked.

"It is true," said Mr. Tesla, "that many scientific minds envisaged the theory of a gaseous ether, but it was rejected again and again because in such a medium longitudinal waves would be propagated with infinite velocity. Lord Kelvin conceived the so-called contractile ether, possessing properties which would result in a finite velocity of longitudinal waves. In 1885, however, an academic dissertation was published by Prof. De Volson Wood, an American, at a Hoboken institution, which dealt with a gaseous ether in which the elasticity, density and specific heat were determined with rare academic elegance. But, so far, everything pertaining to the subject was purely theoretical."

What, then can light be if it is not a transverse vibration? That was the question he asked himself and set out to find the answer.

"I consider this extremely important," said Mr. Tesla. "Light cannot be anything else but a longitudinal disturbance in the ether, involving alternate compressions and rarefactions. In other words, light can be nothing else than a sound wave in the ether."

This appears clearly, Mr. Tesla explained, if it is first realized that, there being no Maxwellian ether, there can be no transverse oscillation in the medium. The Newtonian theory, he believes, is in error, because it fails entirely in not being able to explain how a small candle can project particles with the same speed as the blazing sun, which has an immensely higher temperature.

"We have made sure by experiment," said Mr. Tesla, "that light propagates with the same velocity irrespective of the character of the source. Such constancy of velocity can only be explained by assuming that it is dependent solely on the physical properties of the medium, especially density and elastic force.

Micro-Wave Possibilities.

Coming now to the wireless waves, it is still true that they are of the same character as light waves, only they are not transversal but longitudinal. As a matter of fact, radio transmitters emit nothing else but sound waves in the ether, and if the experts will realize this they will find it very much easier to explain the curious observations made in the application of these waves.

"It being a fact that radio waves are essentially like sound waves in the air, it is evident that the shorter the waves the more penetrative they would be. In 1899 I produced electromagnetic waves from one to two millimeters long and observed their actions at a distance. There has been a great hope expressed by various workers that introduction of these waves will have a revolutionary effect, but I am not sharing the opinion. They will
be used, of course, but to a very limited extent. It is manifest that applications of the very short waves will not produce any appreciable effect upon the wireless art.

"Errors" Retard Wireless Power.

What about the possibilities of power transmission by wireless? the inquirer asked.

Here again Mr. Tesla blames "a strange misconception of the experts" and "grievous errors" for retarding the idea. He believes that when it is accomplished, the power will travel on long waves. He said he could vouch that the scheme of wireless power transmission is entirely practical.

"The application of short waves for power purposes," said Mr. Tesla; "involves complicated and expensive apparatus for rectification or frequency transformation, which would make any serious attempt to carry out a project of this kind much more difficult from an economical point of view."

When will television come around the corner? he was asked.

"It ought to be with us soon, and some day it will be on a par of perfection with broadcasting of music." Then with a circular sweep of his arm and added, "There will be large pictures thrown on the wall."
Other than Tesla and Einstein, this story starts with two individuals, news reporter, Joseph Alsop and physicist, George Gamow. But really, I’m getting ahead of myself. The story of course, really starts with Nikola Tesla, inventor extraordinaire, who, from the start corresponded with, and lectured before so many great scientists: Tom Edison, Guglielmo Marconi, Charles Steinmetz, Elmer Sperry, Sir William Crookes, Sir Oliver Lodge, Lord Kelvin, Heinrich Hertz, Hermann von Helmholtz and Nobel prizewinners Wilhelm Roentgen, JJ Thompson, Lord Raleigh, Ernst Rutherford, Robert Millikan and Albert Einstein himself who wrote Tesla in 1931 to congratulate him on his 75th birthday.

During the pre-internet days, unlike today where if someone today can’t find an answer with the click of a mouse, they give up, real inquiry meant hitting the pavement, travelling to actual research centers to join in on the Tesla quest, to learn as much as we could about this extraordinary individual, and figure out exactly what he was really up to.

My beginnings were modest. I wanted to find out if he was indeed the primary author behind our hydroelectric AC power system, the induction motor, fluorescent and neon lighting, remote control, robotics, wireless communication and a few other inventions. But once you get hooked on Tesla, you enter a much more complex world. Particularly towards the end of his life, Tesla teased the public with a number of more esoteric inventions and theories including his particle beam weapon, a way to harness cosmic rays, his theory on the ether and arguments with
Einstein about curved space, and something he called his “dynamic theory of gravity.”

The following quote is from a little known typewritten paper authored by Tesla in preparation of meeting with the press for his 80th birthday. I found this amazing gem a couple of decades ago buried in the Swezey papers at the Smithsonian Institute in Washington DC.

After... a brief visit to my home in Yugoslavia I returned to this country in 1892 eager to devote myself to the... study of the universe. During the succeeding two years of intense concentration, I was fortunate enough to make two far-reaching discoveries. The first was a dynamic theory of gravity, which I have worked on in all details and hope to give to the world very soon. It explains the causes of this force and the notions of heavenly bodies under its influences so satisfactorily that it will put an end to idle speculation and false conceptions, as that of curved space.... But even if it existed, it would not explain the motions of the bodies as observed. Only the existence of a field of force can account for them and its assumption dispenses with space curvature. All literature on this subject is futile and destined to oblivion. So are also all attempts to explain the workings of the universe without recognizing the existence of the ether and the indispensable function it plays in the phenomena.

My second discovery was a physical truth of the greatest importance. As I have searched the scientific records in more than a half dozen languages for a long time without finding the least anticipation, I consider myself the original discoverer of this truth, which can be expressed by the statement: There is no energy in matter other than that received from the environment. (Tesla, circa 1934, pp. 1-2)

Tesla tells the reader that when he turned 79 he made “a brief reference to it, but its meaning and significance have become clearer to [him] since then. It applies rigorously to molecules and atoms as well as to the largest heavenly bodies and to all matter in the universe in any phase of its existence from its very formation to its ultimate disintegration.”

The paper then goes on to speculate that if this theory is correct, then radioactivity would also be the result of this process, that is, drawing energy from the universe. This led Tesla to study the Sun and cosmic ray production and also to completely dispute Einstein’s theory E=MC², and so Tesla concludes, “the idea that mass is convertible to energy is rank nonsense.... There is no available energy in atomic structures, and even if there were any, the input will always greatly exceed the output.”

From this, it is easy to conclude that Tesla was wrong and Einstein right, as, for instance, the atom bomb clearly showed that there is an enormous amount of energy compacted into the mass of atomic structures, and that, indeed, one can be converted into the other. Yet, the paper goes on to discuss other inventions such as “a new small compact apparatus by which energy in considerable amounts can now be flashed through interstellar space to any distance without the slightest dispersion,” and also a way to create a more efficient vacuum.

So, here I am, in the midst of working on my doctoral dissertation and then working on my Tesla biography, and through this one very obscure paper, Tesla
sends me in several directions and clearly sets up one premise that seems flat out wrong. But I stay with it and twenty years later start to make some sense it.

This brings us to the first man I mentioned above, Joseph Alsop who was a news reporter, and that catchy term, Tesla’s “dynamic theory of gravity.” It had a certain ring that really hit me. In all my research, which took me around the globe to every major archive, participation at numerous Tesla conferences at Colorado Springs, Wardencliffy, Belgrade and Zagreb, discussion and swapping of information with all the Tesla experts, a number of which are here today, and spending a lifetime of daily work on the project, aside from trying to fill in all the other blanks of Tesla’s life, I still wanted to solve this theory and Alsop provided the key.

Joseph Alsop (1910-1989), in his twenties, just two years out of Harvard, was Teddy Roosevelt’s nephew, and thus he had an in with Tesla who happened to be friends with Alsop’s grandmother. In a 1934 interview with the New York reporter who was just beginning his long and famous career, Tesla echoed the information in this obscure paper. In The New York Herald article written exactly 74 years ago tomorrow (July 11, 1934, pp. 1, 15) entitled “Beam to Kill An Army at 200 Miles, Tesla’s Claim,” Tesla tells Alsop a secret, namely that the Sun is absorbing more energy than it is radiating. That is the only reference I ever found to that idea and so I placed it in Wizard, my Tesla biography. This was a big secret which Tesla had kept hidden since its discovery which, one way or another, began in the 1890’s.

Now we come to Albert Einstein and his famous theory of relativity. One caveat, before I continue, namely that I am not a physicist, nor do I pretend to be. I’m a layman trying to understand these difficult concepts. I would also like to state that all, or almost all of the material of this lecture can be found in much greater detail in my book Transcending the Speed of Light: Quantum Physics & Consciousness, which, in a sense, can be seen as part 2 of the Tesla biography.
We need to start with a certain understanding of precisely what gravity is. According to the physicists, it is one of the four known forces of the universe:

- Strong nuclear force holds the nucleus of atoms together.
- Weak nuclear force holds neutrons together.
- Electromagnetism holds molecules together.
- Gravity holds planets and stars together.

Seen in this way, gravity is a binding force. Physicists have been able to mathematically combine the first three forces, but Einstein’s dream of Grand Unification, combining gravity with electromagnetism, has continued to elude them.

![Einstein wishing Tesla a happy 75th birthday and congratulating him for his work in alternating currents.](image)

Yes, I’m a great fan of Einstein, but there are certain things about his theory that always gnawed at me. First of all the theory essentially did away with the ether, or all pervasive medium between the planets and the stars. If light travelled more like a particle than a wave, it did not need an ether to travel through. Twenty years earlier, in the 1880’s, Michelson and Morley tried to detect the ether using mirrors and light beams and they were unable to do so. From this experiment, many wrongly concluded that there was no ether. And so, what happened, and what has continued to happen since Einstein’s 1905 theory, is that the entire 20th century and early part of the 21st century has evolved with the notion that there is no ether. This leaves the notion that space is empty.

However, when you get deeply into the story, you find two very important things: 1) Einstein actually believed in the ether. As quoted in Isaacson’s new biography, Einstein wrote Hendrik Lorentz to state overtly that the ether did indeed exist, and Einstein lectured on the ether at Leiden University in 1920. By its nature, however, Einstein concluded, the ether was simply undetectable. 2) Einstein also said (as quoted in Roland Clark’s earlier biography), that if, indeed the ether could be detected then his theory of relativity was wrong (p. 78). So let’s look at his theory.

We all know that one of the things that Einstein’s theory states is that nothing can travel faster than the speed of light. In fact, no physical thing can travel
as fast as the speed of light because if it did two things would happen. 1) It would obtain infinite mass, and 2) Time would stand still. And both of these things are, of course, impossible. This can be seen in the equation, $M_1$ equals $M_0$ over the square root of 1 minus $v^2$ over $c^2$, which is derived from Lorentz’ work:

$$M_1 = \frac{M_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where:

$M_1$ = new mass  
$M_0$ = old mass  
$v$ = velocity  
$c$ = speed of light

You can see as the velocity, $v$ approaches $c$, the denominator approaches zero, thus $M_0$ gets divided by a smaller and smaller number so $M_1$ gets infinitely large. For Time, one need simply replace $M$ with $T$. As $v$ approaches $c$, Time becomes infinite, and in that sense, no longer exists. Time would stand still.

I’d like to read a section from Isaacson’s fine biography on Einstein. This is in his chapter on Special Relativity:

For the special case of observers moving at a constant velocity, this concept is pretty easy to accept. Imagine a man in an armchair at home and a woman in an airplane gliding smoothly above. Each can pour a cup of coffee, bounce a ball, shine a flashlight, or heat a muffin in a microwave and have the same laws of physics apply. In fact, there is no way to determine which of them is ‘in motion’ and which is ‘at rest.’ The man in the armchair could consider himself at rest and the plane in motion. And the women in the plane could consider herself at rest and the earth as gliding past. There in no experiment that can prove who is right. (Isaacson, 2007, p. 107)

Well, I could think of an experiment: punch a hole in the fuel tank and wait a few minutes. What Einstein is leading up to is that everything is relative. There is no absolute time. But I say, with respect, who cares if the guy in the chair or the lady on the plane can’t tell which one is moving? Ultimately, what does this have to do with Einstein’s real argument that absolute time does not exist. The simple fact of the matter is, the guy in the chair is at rest (forgetting the movement of the Earth for a minute), and the lady in the plane is in flight. What Einstein is trying to do is get away from the elephant in the room, the movement of the Earth around the Sun. That is how we tell time. One hour is 1/24th rotation of the Earth, a day is 1/365th of the Earth’s path around the Sun and so on.

As my book Transcending the Speed of Light speculates, why should Einstein care one iota what an observer sees or thinks? Consciousness as a force in and of itself, is completely ignored by he and all the physicists and yet they are basing this entire theory on the very process of subjective observation. Stand twenty yards away and you will see the guy sitting still in his chair and the lady flying in her plane. So I disagree with Einstein. There is absolute time which is directly related to the movement of the Earth, Sun and stars, and the NOW is the same instant all over the cosmos.
When it comes to researching the history of the study of the ether, one finds a lot of things aside from the fact that every physicist prior to the 20th century believed in it (e.g., Maxwell, Faraday, Oersted, Kelvin, Fitzgerald, Lorentz, etc.). Let's start with the obvious. Look at this picture of several galaxies. Clearly, they are floating in something. This is not empty space. We are looking at the ether. Now, let's consider a galaxy's length such as our modest-sized galaxy, the Milky Way. We are told it is 90,000 light-years long. Now multiply that figure times a single light-year which is six thousand trillion miles! Frankly, the length of the Milky Way, or the Andromeda Galaxy, which is in the top left of this picture, is incomprehensible. And here it is, the entire entity seen in one picture! So we have a couple of things to consider. One is, that we can easily see expanses that make the speed of light as a measuring stick an absurdity. And what about the galaxy itself? Clearly, there must be some kind of instantaneous mechanism for connecting one side of itself to its other side. We could call it, its angular momentum. And if we think of the galaxy as being held together by some kind of overarching force-field, that force-field makes a mockery of the speed of light. It must, by necessity, exist in some tachyonic or faster than the speed of light realm.

Now, we come to our second key man, George Gamow. Born in 1904, schooled at the University of Leningrad in Russia, Gamow (1904-1968) continued his studies at Gottingen, Germany where Einstein and seemingly every other major leader in the field often taught (e.g., Minkowski, Hilbert, Klein, von Karmen, Born). Working as a theoretical physicist, Gamow then taught at the University of Copenhagen before studying with Ernst Rutherford at Cambridge which would be in the early 1930’s. Forced to return to Russia, he fled to the United States and eventually taught at Berkeley. Gamow’s work on cosmology played crucial roles in the Big Bang theory and in the Nobel Prize which was awarded to Arno Penzias and Robert Wilson which they earned ten years after Gamow’s death. He is one of the founding fathers of modern day quantum physics and a famous author of many popular books on the topic.

In Gamow’s little masterpiece, _Thirty Years That Shook Physics_, he says some astonishing things. In the 1920’s, physicists were trying to measure the movement of electrons and during these studies, Goudsmit and Uhlenbeck made a startling
discovery. They found that electrons were spinning considerably faster than the speed of light! Gamow states overtly that this finding did not violate anything in quantum mechanics. What it violated was Einstein’s theory of relativity.

What were the physicists to do? If Goudsmit and Uhlenbeck were right then relativity was wrong. Here is where the story takes a surprising turn. One of my criticisms of Isaacson’s new biography on Einstein is that Isaacson delegates Hermann Minkowski to almost non-person status. Yes, he is mentioned, but his real contribution to Einstein’s thinking is distorted and obscured. Don’t get me wrong, this is a superb biography, well worth the read, but it is flawed and this is one of its biggest flaws.

One of Einstein’s goals was to combine three dimensions of space with one dimension of time in his calculations. Minkowski, who was an abstract mathematician, gave Einstein, the physicist, the key. It was the imaginary number i, or the square root of negative 1 which, of course, can’t exist. The reason is simple. A negative times a negative always equal’s a positive. The square root of 1 is 1. One times one is one. Negative one times negative one also gives you positive one. However, if you square i, by definition, you get -1. So, i is imaginary, and the introduction of i, which was associated with the time coordinate, could now be made equivalent to 3D space. This use of abstract mathematics allowed Einstein to combine space with time. Minkowski plays a huge role in helping Einstein formalize his theory, but you’d never know it from reading Isaacson’s biography. Further, and most importantly, it took an imaginary number, that is, a number that can only exist in the mind, to better explain physical phenomena. This simple fact has far reaching implications as to the nature of mind and its relationship to the fundamental structure of the cosmos.

Getting back to Gamow’s story, here is where Paul Adrian Dirac comes along. What Dirac did was save the day by copying this process, that is to say, he replaced...
the tachyonic spinning, relativity-violating electron, with Minkowski’s imaginary number $i$. And by doing so, Dirac was able to combine relativity with quantum mechanics and he got the Nobel Prize for this! specifically for developing “new productive forms of atomic theory.” He was 31 years old!

Take a moment and look up Dirac and do some research on him and you will find that the real nature of his Nobel Prize has been obscured. He did not disprove Goudsmit and Uhlenbeck’s findings, he simply replaced the troublesome fact they uncovered with an imaginary number. So, look what Gamow is telling us. Electrons spin at speeds faster than the speed of light, but to say this, or even think it would cause a physicist to be kicked out of the club that worships relativity.

One person who is not part of this club is PD Ouspensky, the Russian theoretician on abstract mathematics and higher states of consciousness. Ouspensky explains how we get from one dimension to the next (see figure above). It involves movement and orthorotation or spin. For instance, we all know what a plane is. It is a two-dimensional surface. In a famous *The Simpsons* episode, Homer, who had lived his whole life in a 2D world, enters the third dimension. But how does he get there?

Let’s start with the zero dimension which is a dot. When the dot spins and moves out, it becomes a line, which is the first dimension. When the line moves out at right angles to itself, it becomes a plane, which is the second dimension and when the plane moves up at right angles to itself, it becomes a cube. A line is made up of an infinite number of dots. A plane is made up of an infinite number of lines and a cube is made up of an infinite number of planes stacked onto each other. So to change dimensions, one needs a $90^\circ$ twist or spin and movement out, and further, the higher dimension is infinity to the dimension beneath it.

What Ouspensky states in his epic book *New Model of the Universe*, is that what Einstein came across with $E=MC^2$ was an instance of infinity when velocity achieves lightspeed. What Einstein really discovered was a door to the next dimension, a realm we could call hyperspace or, perhaps, innerspace. Time doesn’t stand still, time is transcended. My book *Transcending the Speed of Light* hypothesizes that our minds are already one step higher than the physical
dimension and in that sense, we are living in inner space, a place which already operates in a tachyonic or faster than lightspeed realm. For instance, time for our minds has very little meaning. I haven’t seen the Corum brothers, Jim Hardesty or Gary Peterson for a couple of years, but it makes no difference in my mind. It’s as if I saw them yesterday. That’s how the mind works.

Now to get back to Tesla and his dynamic theory of gravity. After studying on the internet such ether theorists as Price and Gibson, Mikhail Shapkin, David Wilcox and Ron Hatch, I have been able to compile the final pieces to Tesla’s theory. And as with most great theories, it is rather simple. What Tesla is saying is that mass is absorbing energy or ether all the time. The reason the Sun can continue to radiate light without burning out is because it is a conduit, constantly absorbing more energy than it is radiating, and that is what gravity is. All matter absorbs energy all the time. This also is the so-called God particle or Higgs boson, the particle that gives matter its mass. It’s not really a particle, it’s an ongoing process of ether absorption.

Take the Earth, for instance. The reason that we fall back to the Earth is not because of some mystical force of gravity. It is precisely for the reason Tesla said, “There is no energy in matter other than that received from the environment.” The Earth, as with all matter, is constantly absorbing etheric energy. So, when we jump up, the reason we fall back down is because we are in the way of this influx. That is what gravity is. It is the absorption of ether by the planet.

The etheric theory also explains why light is a constant speed. Just as sound is slowed down by air, light is slowed down by the medium of the ether. A question raised then could be, what precisely is the ether? My guess is that it is a very high frequency AC field oscillating at a tachyonic rate in some harmonic relationship to the speed of light. But, the primary structure of space also has another level to it, and that would be light itself.

We know that the universe is expanding. At some point, when it all began, when galaxies and stars began to form, they also began to radiate light. Thus, if we were to place a telescope at any point in space we would be able to see,
theoretically, every star. No matter where you place the telescope you will be able to see all the galaxies and stars, just from different angles. What this means is that every point in space contains the intersecting light from every star, and further, that each point codes for every other point. Each part reflects the whole. This is a holographic construction made from this grid of light-beams emanating from every galaxy and star. And this network, in some kind of way, is superimposed over what we are calling the ether.

Further, if, on some level, we take Einstein at his word, that mass and energy are equivalent, this suggests that photons, or light particles are not really massless. If they have energy, by definition, they must also have mass, a tiny amount to be sure, but mass, none-the-less. And if photons have mass, remember, they have the capability to knock electrons out of their orbits, then this suggests that the so-called dark (e.g., invisible) matter that no one can seem to find, is not really dark at all. It is light itself. So the missing matter would be the aggregate of all the light that has been emanating from the stars and galaxies since the beginning of time, spread in a holographic grid throughout all of space.

So, if the primary substrate of the universe is indeed ether, an alternative theory for the Big Bang also arises. First Cause may have been started by two currents, Yin and Yang, criss-crossing out of phase with each other, which of course would be associated with Tesla’s rotating magnetic field. This theory better explains the oscillating/electronic nature of the universe and the primacy of spin.

Where Einstein was right was in seeing a link between acceleration and gravity, what we call a G-force. This new view of his which gave space property (Isaacson, p. 318), came about because of his new need to emphasize the wave aspect more than the particle aspect of photons. That was because around 1915-1920 a greater emphasis on wave theory emerged, as espoused by deBroglie and Einstein wanted to be part of this new development.

According to ether theory, if a body moves rapidly through the ether, its absorption rate increases as does its weight. This suggests that Michelson and Morley were wrong. The ether is quite easy to detect. We feel the ether when we jump up, hurl a discus, or when we accelerate in a car or a plane. Ether flowing through matter is gravity. Matter flowing through ether is acceleration (that’s what a G-force is).

Electrons are constantly absorbing ether and that is how they maintain their spin. At the same time, this energy is converted into electromagnetism. This new view of ether, gravity, mass, particle spin and electromagnetism evolves directly from Tesla’s dynamic theory of gravity, and it also explains Einstein’s biggest dilemma, Grand Unification, the attempt to combine gravity with electromagnetism. As you learn in the Isaacson biography, Einstein spent the last half of his life seeking Grand Unification and he never got there.

This is the reason why. Had he truly resurrected the ether and had he considered Tesla’s theory as reported by Alsop in The Herald Tribune, Einstein would have realized that relativity is incomplete. There are energies that travel faster than the speed of light. The reason that photons curve around stars and planetary bodies is because they are being sucked into this influx like everything
else. The curved space that Einstein saw was really the warping of ether as it is being sucked into great planetary and stellar bodies. This theory also explains why the ground connection was so important to Tesla’s wireless transmitter. Once he sent an impulse out, that impulse tended to follow the surface of the Earth because it was being deflected downward by the constant influx of ether by the Earth.

Yes, Tesla was wrong about some aspects of Einstein’s theory. It is unfortunate that he did not live to see the atomic age. It would be interesting to speculate how this new information would have altered his thinking. But at the same time, Einstein was blind to Tesla’s etheric theory. Intuitively, Einstein realized that if he spent too much time resurrecting the ether, his precious theory of relativity would suffer. With blinders on, present-day physicists continue to ignore Gamow’s book and his reporting of the findings of Goudsmit and Uhlenbeck. They use imaginary numbers instead, to make up terms like the God particle, to try and find this supposed coupling mechanism that gives matter its mass. When to really find what they are looking for, they need to step outside their present day theories and embrace the thinking of the man they try so hard to ignore, Nikola Tesla.

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Einstein had really postulated two theories. The special theory of relativity postulated in 1905, dealing with uniform motions, and the general theory, which dealt with motions speeding up and slowing down. Mach's principle is linked to the general theory.


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"The first thing to realize about the ether is its absolute continuity. A deep sea fish has probably no means of apprehending the existence of water; it is too uniformly immersed in it: and that is our condition in regard to the ether." - Sir Oliver Lodge, Ether and Reality

Nikola Tesla used ancient Sanskrit terminology in his descriptions of natural phenomena. As early as 1891 Tesla described the universe as a kinetic system filled with energy which could be harnessed at any location. His concepts during the following years were greatly influenced by the teachings of Swami Vivekananda.

Swami Vivekananda was the first of a succession of eastern yogi's who brought Vedic philosophy and religion to the west. After meeting the Swami and after continued study of the Eastern view of the mechanisms driving the material world, Tesla began using the Sanskrit words Akasha, Prana, and the concept of a luminiferous ether to describe the source, existence and construction of matter. This paper will trace the development of Tesla's understanding of Vedic Science, his correspondence with Lord Kelvin concerning these matters, and the relation between Tesla and Walter Russell and other turn of the century scientists concerning advanced understanding of physics. Finally, after being obscured for many years, the author will give a description of what he believes is the pre-requisite for the free energy systems envisioned by Tesla.

By the year 1891, Nikola Tesla had invented many useful devices. These included a system of arc lighting (1886), the alternating current motor, power generation and transmission systems (1888), systems of electrical conversion and distribution by oscillatory discharges (1889), and a generator of high frequency currents (1890), to name a few.

The most well known patent centers around an inspiration that occurred while walking with a friend in a park in Budapest, Hungry. It was while observing the sunset that Tesla had a vision of how rotating electromagnetic fields could be used in a new form of electric motor. This led to the well known system of alternating current power distribution. In 1891 however, Tesla patented what one day may become his most famous invention. It is the basis for the wireless transmission of electrical power and is know as the Tesla Coil Transformer. It was during this year that Tesla made the following comments during a speech before the American Institute of Electrical Engineers;

“Ere many generations pass, our machinery will be driven by a power obtainable at any point in the universe. This idea is not novel… We find it in the delightful myth of Antheus, who derives power from the earth; we find it among the subtle speculations of one of your splendid mathematicians… Throughout space there is energy. Is this energy static or kinetic.? If static our hopes are in vain; if kinetic - and this we know it is, for certain - then it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of nature.”

This description of the physical mechanisms of the universe was given before Tesla became familiar with the Vedic science of the eastern Nations of India, Tibet, and Nepal. This science was first popularized in the United States and the west during the three year visit of Swami Vivekananda.
VEDIC SCIENCE AND SWAMI VIVEKANANDA

The Vedas are a collection of writings consisting of hymns, prayers, myths, historical accounting, dissertations on science, and the nature of reality, which date back at least 5,000 years. The nature of matter, antimatter, and the make up of atomic structure are described in the Vedas. The language of the Vedas is known as Sanskrit. The origin of Sanskrit is not fully understood. Western scholars suggest that it was brought into the Himalayas and thence south into India by the southward migrations of the Aryan culture. Paramahansa Yogananda and other historians however do not subscribe to that theory, pointing out that there is no evidence within India to substantiate such claims.

There are words in Sanskrit that describe concepts totally foreign to the western mind. Single words may require a full paragraph for translation into English. Having studied Sanskrit for a brief period during the late 70’s, it finally occurred to this writer that Tesla’s use of Vedic terminology could provide a key to understanding his view of electromagnetism and the nature of the universe. But where did Tesla learn Vedic concepts and Sanskrit terminology? A review of the well known biographies by Cheney, Hunt and Draper, and O’Neil 3,4,5, reveal no mention of Tesla’s knowledge of Sanskrit. O’Neal however includes the following excerpt from an unpublished article called Man’s Greatest Achievement:

“There manifests itself in the fully developed being, Man, a desire mysterious, inscrutable and irresistible: to imitate nature, to create, to work himself the wonders he perceives.... Long ago he recognized that all perceptible matter comes from a primary substance, or tenuity beyond conception, filling all space, the Akasha or luminiferous ether, which is acted upon by the life giving Prana or creative force, calling into existence, in never ending cycles all things and phenomena. The primary substance, thrown into infinitesimal whirls of prodigious velocity, becomes gross matter; the force subsiding, the motion ceases and matter disappears, reverting to the primary substance.”

According to Leland Anderson the article was written May 13th, 1907. Anderson also suggested that it was through association with Swami Vivekananda that Tesla may have come into contact with Sanskrit terminology and that John Dobson of the San Francisco Sidewalk Astronomers Association had researched that association.

Swami Vivekananda was born in Calcutta, India in 1863. He was inspired by his teacher, Ramakrishna to serve men as visible manifestations of God. In 1893 Swami Vivekananda began a tour of the west by attending the Parliament of Religions held in Chicago. During the three years that he toured the United States and Europe, Vivekananda met with many of the well known scientists of the time including Lord Kelvin and Nikola Tesla.

According to Swami Nikhilananda:

Nikola Tesla, the great scientist who specialized in the field of electricity, was much impressed to hear from the Swami his explanation of the Samkhya cosmogony and the theory of cycles given by the Hindus. He was particularly struck by the resemblance between the Samkhya theory of matter and energy and that of modern physics. The Swami also met in New York Sir William Thompson, afterwards Lord Kelvin, and Professor Helmholtz, two leading representatives of western science. Sarah Bernhardt, the famous French actress had an interview with the Swami and greatly admired his teachings.

It was at a party given by Sarah Bernhardt that Nikola Tesla probably first met Swami Vivekananda. Sarah Bernhardt was playing the part of ‘Iziel’ in a play of the same name. It was a French version about the life of Bhudda. The actress upon seeing Swami Vivekananda in the audience, arranged a meeting which was also attended by Nikola Tesla. In a letter to a friend, dated February 13th, 1896, Swami Vivekananda noted the following:
Mr. Tesla was charmed to hear about the Vedantic Prana and Akasha and the Kalpas, which according to him are the only theories modern science can entertain. Mr Tesla thinks he can demonstrate that mathematically that force and matter are reducible to potential energy. I am to go see him next week to get this mathematical demonstration.

Swami Vivekananda was hopeful that Tesla would be able to show that what we call matter is simply potential energy because that would reconcile the teachings of the Vedas with modern science. The Swami realized that “In that case, the Vedantic cosmology [would] be placed on the surest of foundations”. The harmony between Vedantic theories and and western science was explained by the following diagram:

\[
\begin{align*}
\text{BRAHMAN} &= \text{THE ABSOLUTE} \\
\text{MAHAT OR ISHVARA} &= \text{PRIMAL CREATIVE ENERGY} \\
\text{PRANA and AKASHA} &= \text{ENERGY and MATTER}
\end{align*}
\]

Tesla understood the Sanskrit terminology and philosophy and found that it was a good means to describe the physical mechanisms of the universe as seen through his eyes. It would behoove those who would attempt to understand the science behind the inventions of Nikola Tesla to study Sanskrit and Vedic philosophy.

Tesla apparently failed to show the identity of energy and matter. If he had, certainly Swami Vivekananda would have recorded that occasion. The mathematical proof of the principle did come until about ten years later when Albert Einstein published his paper on relativity. What had been known in the East for the last 5,000 years was then known to the West.

Brahman is defined as the one self existent impersonal spirit; the Divine Essence, from which all things emanate, by which they are sustained, and to which they return. Notice that this is very similar to the concept of the Great Spirit as understood by Native American cultures.

Ishvara is the Supreme Ruler:

the highest possible conception of the Absolute, which is beyond all thought.

Mahat means literally the Great One, and is also interpreted as meaning universal mind or cosmic intelligence. Prana means energy (usually translated as life force) and Akasha means matter (usually translated as ether). Dobson points out that the more common translations for Akasha and Prana are not quite correct, but that Tesla did understand their true meanings.

The meeting with Swami Vivekananda greatly stimulated Nikola Tesla’s interest in Eastern Science. The Swami later remarked during a lecture in India, “I myself have been told by some of the best scientific minds of the day, how wonderfully rational the conclusions of the Vedanta are. I know of one of them personally, who scarcely has time to eat his meal, or go out of his laboratory, but who would stand by the hour to attend my lectures on the Vedanta; for, as he expresses it, they are so scientific, they so exactly harmonize with the aspirations of the age and with the conclusions to which modern science is coming at the present time”.

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Reflections on the Mind of Nikola Tesla

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27 August 2006

Abstract: Nikola Tesla was a complex genius whose prolific mind produced many electrical marvels. In this paper, we focus on only four of his documented mental characteristics: (1) an extremely acute sense of hearing and sight; (2) a visualization so vivid as to mimic reality; (3) eccentricities of habit and behaviour; and (4) making grandiose claims, some of which remain open until today. Each of these is examined in some detail, especially with respect to his creativity, and questions worthy of further investigation are posed. Finally, the hypothesis of mental evolution, as proposed by R M Bucke, is put forward as a possible explanation for Tesla’s prodigious and rare mind.

Keywords: Tesla, mind, creativity, visualization, mental evolution, eureka moment, virtual laboratory

1 Introduction

Nikola Tesla was a prodigious genius who benefited mankind immensely. He embodied a strange combination of fiery imagination, more suited to the poet or artist, tempered by the discipline of the engineer, grounded in mathematics and experimental science. The fact that he worked mostly alone and produced baffling inventions has led to his being labelled as both sorcerer and genius. He was superhuman in his will power and in his appetite for work. Yet he was also a frail human being who suffered a nervous breakdown, who had a fixation on the number three, and who, in later life, made bizarre claims which alienated him from mainstream science. Although he was well recognized by his scientific peers and the media in the late nineteenth and early twentieth century, Tesla today remains a largely unknown and unsung hero who has not been accorded his rightful place in history. It is also ironic that although others profited immensely from his inventions, Tesla himself did not enjoy a prosperity commensurate with his abilities or contributions, and died alone and in penury.

It is impossible to review the visionary contributions of Tesla within the compass of one paper, let alone do justice to analyzing his unique mind. Only certain aspects of Tesla’s mind will concern us here; the interested reader is referred to brief synopses and fuller accounts of his life and writings elsewhere [1, 2, 3, 4, 5, 6, 7, 8, 9]. In this paper, we focus on only four of his documented mental characteristics:

1. An extremely acute sense of hearing and sight;
2. A power of visualization so vivid as to mimic reality;
3. Eccentricities of habit and behaviour; and
4. Making grandiose claims, some of which remain open until today.

In each case, evidence is furnished from Tesla’s own writings, his biographies, or from the other available literature. Each of these traits is examined in some detail, especially with respect to his creativity. Comparisons are made with other well known scientists with similar characteristics, and speculative comments are made, along with a list of questions worthy of further investigation. Finally, a hypothesis is put forward—based on the idea of mental evolution, as proposed by R M Bucke [10]—as one possible explanation for Tesla’s prodigious and rare mind.

2 Tesla’s hypersensitive hearing and sight

From a young age, Tesla had hypersensitive hearing and sight. For example, he recounted [3] that in his boyhood, he saved his neighbours’ lives when he heard the crackling of flames consuming their homes at night. At the age of 25, he suffered what was termed by his doctors a “nervous breakdown” for want of a better term. While he was ill, Tesla’s pulse varied from a few beats to two hundred and sixty beats per minute and all the tissues of his body quivered and twitched [1]. During the period he was ill, Tesla had the following extraordinary aural experiences [3, 1]:

1. He could hear the sound of a watch ticking three rooms away;
2. A fly landing on a table in his room caused a dull thud in his ear;
3. A carriage passing several kilometres distant caused his whole body to shake;
4. He could not endure the vibration in his chair caused by a train whistle thirty-two kilometres away;
5. Rubber cushions had to be placed under his bed so that he could rest undisturbed by the vibrations of sounds around him; and
6. In the dark, like a bat, he could sense an object at a distance of about four metres by a peculiar creepy sensation on the forehead.

Even when Tesla was past forty, and conducting research into lightning in the Colorado mountains, in the USA, he could hear thunderclaps 880 kilometres away, whereas his assistants, at half his age, could only hear them up to 240 kilometres away [3, 1].

Not only was his hearing acute, Tesla’s sense of sight was incredible. It enabled him to perform what may be termed peregrinations of the mind. Let us hear it in his own words:

In my boyhood I suffered from a peculiar affliction due to the appearance of images, often accompanied by strong flashes of light, which marred the sight of real objects and interfered with my thought and action. They were pictures of things and scenes which I had really seen, never of those I imagined. When a word was spoken to me the image of the object it designated would present itself vividly to my vision and sometimes I was quite unable to distinguish whether what I saw was tangible or not. This caused me great discomfort and anxiety…

Then I instinctively commenced to make excursions beyond the limits of the small world of which I had knowledge, and I saw new scenes. These were at first very blurred and indistinct, and would flit away when I tried to concentrate my attention upon them,
but by and by I succeeded in fixing them; they gained in strength and distinctness and finally assumed the concreteness of real things. I soon discovered that my best comfort was attained if I simply went on in my vision farther and farther, getting new impressions all the time, and so I began to travel—of course, in my mind. Every night (and sometimes during the day), when alone, I would start on my journeys—see new places, cities and countries—live there, meet people and make friendships and acquaintances and, however unbelievable, it is a fact that they were just as clear to me as those in actual life and not a bit less intense in their manifestations. [1](emphasis is mine)

Here we see that it was not a hypersensitivity to an actual stimulus, but the sensation of vision that had verisimilitude, without the need for any external stimulus, that is singular.

2.1 Questions and conjectures: hearing and sight

The following questions and conjectures arise regarding Tesla’s unusual hearing and sight:

1. Was Tesla’s mind influenced in any way by his heightened and unusual sensory awareness?
2. If so, what was the cause-effect relationship?
   a. Were his hyper-acute senses responsible for his mental powers?
   b. Or did his sensory acuity arise from his amazing mental faculties?
3. Were his sightseeing journeys a form of vivid daydreaming, or were they hallucinations, or were they some other as yet unlabelled phenomenon?
4. Did his “nervous breakdown” influence his inventive abilities?
5. Were his eccentric habits and behaviour in later life the sequela of his “nervous breakdown”?

It is believed that these and other questions posed here are worthy of further investigation by specialist researchers; the answers to them are likely to shed light on many aspects of the creative scientific process.

3 Tesla’s vivid visualization and mental experiments

If Tesla’s hyper-acute senses marked him out as unusual, his vivid visualization and extremely efficient method for realizing his inventions are unique in the annals of the history of science. Tesla not only discovered hidden forces and sources of energy, but he also designed machines that made practical use of his discoveries for the benefit of humanity. Thus, not only was he an applied mathematician and experimental scientist, he was also a highly accomplished engineer, but one whose methods were atypical. We will here first examine in some detail the genesis of the invention of the induction motor that came about from his grasping the idea of rotating magnetic fields. This is followed by a brief recountal and analysis of the discovery of the benzene ring by the chemist Kekulé. Then we will explore and discuss Telsa’s vivid faculty of visualization, and compare it with similar instances from other well known scientists. This section is concluded with a discussion of the process of scientific discovery and creativity.
3.1 The AC induction motor

In 1875, at the age of 19, Tesla enrolled at the Polytechnic Institute at Graz in Austria to study electrical engineering. In his second year there, his professor demonstrated a direct current (DC) motor for the first time. Tesla was impressed but objected to the sparking that he saw taking place at the commutator. His professor replied that the sparking was inevitable, being inherent in the design of the machine. Tesla was unconvinced and felt that there must be some way to circumvent the use of commutators. He felt inwardly assured that there was a solution to this problem, although his instructors did not share this view [2]. He later used these words to describe this inner certitude:

In attacking the problem again I almost regretted that the struggle was soon to end. I had so much energy to spare. When I undertook the task it was not with a resolve such as men often make. With me it was a sacred vow, a question of life and death. I knew that I would perish if I failed. Now I felt that the battle was won. Back in the deep recesses of the brain was the solution, but I could not yet give it outward expression. [1]

Paradoxically, the demonstration of the DC motor had convinced him that by using alternating current (AC) with its changing direction of current flow, the commutator could be eliminated altogether. While he felt an inner assurance that it could be done, what he did not know was how to accomplish it [2]. The answer came to him, not by logical reasoning, but by a flash of insight that he later described in these words:

I could not demonstrate my belief at that time, but it came to me through what I might call instinct, for lack of a better name. But instinct is something which transcends knowledge. We undoubtedly have in our brains some finer fibres which enable us to perceive truths which we could not attain through logical deduction, and which it would be futile to attempt to achieve through any wilful effort of thinking. [2, p 49]

After six years of intensive thought, Tesla did finally get the revelation that revolutionized our world: the AC induction motor and, concomitantly, the AC generator. It occurred in Budapest during a walk in the late afternoon that he took with a friend in February 1882. The full flavour of the revelation that dawned on him is best conveyed by his own words:

One afternoon, which is ever present in my recollection, I was enjoying a walk with my friend in the City Park and reciting poetry. At that age I knew entire books by heart, word for word. One of these was Goethe’s Faust. The sun was just setting and reminded me of the glorious passage:

Sie rückt und weicht, der Tag ist überlebt,
Dort eilt sie hin und fördert neues Leben.
O, daß kein Flügel mich vom Boden hebt,
Ihr nach und immer nach zu streben!

Ein schöner Traum, indessen sie entweicht,
Ach, zu des Geistes Flügeln wird so leicht
Kein körperlicher Flügel sich gesellen!
The glow retreats, done is the day of toil;
It yonder hastes, new fields of life exploring;
Ah, that no wing can lift me from the soil
Upon its track to follow, follow soaring!

A glorious dream! though now the glories fade.
Alas! the wings that lift the mind no aid
Of wings to lift the body can bequeath me.

As I uttered these inspiring words the idea came like a flash of lightning and in an instant the truth was revealed. I drew with a stick on the sand the diagrams shown six years later in my address before the American Institute of Electrical Engineers, and my companion understood them perfectly. The images I saw were wonderfully sharp and clear and had the solidity of metal and stone, so much so that I told him: “See my motor here; watch me reverse it.” I cannot begin to describe my emotions. Pygmalion seeing his statue come to life could not have been more deeply moved. A thousand secrets of nature which I might have stumbled upon accidentally I would have given for that one which I had wrested from her against all odds and at the peril of my existence. [1]

Writing in the Scientific American, Tesla explains this revelation further:

It is extremely difficult for me to put this experience before the reader in its true light and significance for it is so altogether extraordinary. When an idea presents itself it is, as a rule, crude and imperfect. Birth, growth and development are phases normal and natural. It was different with my invention. In the very moment I became conscious of it, I saw it fully developed and perfected. [11]

Figure 1: This is one of the two two-phase induction motors demonstrated by Tesla in his historic lecture of 16 May 1888, before the American Institute of Electrical Engineers at Columbia University. The motor developed 1/2 horsepower and showed that brushes and commutators could be eliminated. This image and the information in its caption are taken from the PBS (Public Broadcasting System) web site on Tesla [12].

In his own mind, the idea of the rotating magnetic fields, one chasing the other, that formed the basis of the induction motor and the AC generator, was the greatest secret that he had plucked from Nature. Ever since he first saw the DC motor with its commutator and sparking, he had resolved to invent a motor that did away with those features. After six years of protracted thought and indefatigable effort, he had at last
succeeded, but he paid a price by suffering from a “nervous breakdown” soon thereafter.

### 3.2 Archimedes, the eureka moment, and incubation

There are two well-known instances of scientific discoveries that occurred as flashes of insight after protracted mental effort at problem solving, not unlike Tesla’s vision of the rotating magnetic fields. The first is that of Archimedes as he was in his bath. When he saw the water overflow as he sank into the bath, he spontaneously saw the solution to his problem. Oblivious to his nakedness, he ran unclad along the streets of Syracuse, proclaiming “Eureka!” (I have found it!). Such nodal points of scientific discovery may be called eureka moments.

Tesla’s eureka moment regarding the induction motor, and conversely AC power generation, occurred during an evening walk with his friend, as we have already seen. Such insights are often the result of sustained thinking on a topic, with a subsequent relaxation, as in Archimedes’s bath or Tesla’s walk, when unheralded, “the penny drops” and the solution is revealed, apparently without any immediate conscious effort on the part of the scientist. The mathematician Jules Henri Poincaré believed that after prolonged thinking on a problem, there is a period of incubation or unconscious thought, after which the solution would pop up spontaneously, and seemingly without conscious effort [13, p 15].

### 3.3 Kekulé and the benzene ring

Another historically documented eureka moment that occurred after incubation was the elucidation of the structural formula of benzene, by the organic chemist, Frederich August Kekulé. It occurred in a now-famous series of dreams.

The difficulty was that the hitherto known compounds of carbon were composed of chains of carbon atoms “connected” or bonded to each other and to hydrogen atoms. These bonds all obeyed the rule that each carbon atom must have four bonds. The molecule of benzene, C6H6, was composed of six carbon atoms and six hydrogen atoms. Try as he might, Kekulé could not reconcile this formula with any structural arrangement of the atoms that satisfied the requirement for four bonds per carbon atom. He mulled over the problem for some time before he got the solution which changed organic chemistry forever. There are actually two episodes. The first was in London, when he saw the atoms dancing while he was travelling in a bus. Later, in 1865 while writing his textbook at Ghent in Belgium, Kekulé had the following experience:

I turned my chair to the fire and dozed. Again the atoms were gambolling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by repeated visions of the kind, could now distinguish larger structures of manifold conformation; long rows, sometimes more closely fitted together; all twining and twisting in a snake-like motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I woke. [14, p 43 ]

An impressive video dramatization of Kekulé’s dream is available on the Web [15]. It is interesting that, instead of “dozed”, the original German word used by Kekulé in his
description of the second dream was “Halbschlaf” which literally means “half-asleep” [13, p 32]. So, it is clear that the revelation came to him during a period in the twilight state between wakefulness and sleep.

3.4 Vivid visualization and mental experiments

Tesla possessed unique powers of visualization. He could volitionally form in his mind pictures of objects that did not exist in the outside world, and that he did not see with his eyes, but which were just as clear to his visual sense as actual objects seen with the eyes. At the age of seventeen, he started seriously applying this unusual faculty toward his inventions. As he recounted it:

…Then I observed to my delight that I could visualize with the greatest facility. I needed no models, drawings or experiments. I could picture them all as real in my mind. Thus I have been led unconsciously to evolve what I consider a new method of materializing inventive concepts and ideas, which is radically opposite to the purely experimental and is in my opinion ever so much more expeditious and efficient. The moment one constructs a device to carry into practice a crude idea he finds himself unavoidably engrossed with the details and defects of the apparatus. As he goes on improving and reconstructing, his force of concentration diminishes and he loses sight of the great underlying principle. Results may be obtained but always at the sacrifice of quality.

My method is different. I do not rush into actual work. When I get an idea I start at once building it up in my imagination. I change the construction, make improvements and operate the device in my mind. It is absolutely immaterial to me whether I run my turbine in thought or test it in my shop. I even note if it is out of balance. There is no difference whatever, the results are the same. In this way I am able to rapidly develop and perfect a conception without touching anything. When I have gone so far as to embody in the invention every possible improvement I can think of and see no fault anywhere, I put into concrete form this final product of my brain. Invariably my device works as I conceived that it should, and the experiment comes out exactly as I planned it. In twenty years there has not been a single exception. Why should it be otherwise? Engineering, electrical and mechanical, is positive in results. There is scarcely a subject that cannot be mathematically treated and the effects calculated or the results determined beforehand from the available theoretical and practical data. The carrying out into practice of a crude idea as is being generally done is, I hold, nothing but a waste of energy, money and time.

Thus, Tesla produced his inventions without drawings or blueprints. He did not have computers like we do, to conduct inexpensive and complex simulations before building prototypes. Indeed he generally did not build physical prototypes for his inventions. Instead, he conducted all the preliminary work for the machines he built entirely in his mind. It is only after he had satisfactorily concluded those mental experiments that he proceeded with physical fabrication of the devices.

It is a curious fact that once Tesla started an experiment, say switching on a motor and keeping it running for several days, he could devote his mind to other tasks while the running motor experiment carried along on its own, without conscious intervention from him, until he decided to switch the motor off and examine the wear and tear. This
is a form of multitasking which those who are familiar with computing will understand, as the ability of an operating system to process several computing tasks by attending to each of them sequentially in specific slices of time, giving rise to the illusion of simultaneity. But even this analogy is flawed because in a computer only one task is performed at any one time, whereas the experiment in Tesla’s mind ran automatically without conscious intervention from him, while he attended to other tasks.

Moreover, Tesla asserts that his mental experiments never failed him once in a long and fecund inventing career. Even more surprisingly, “his memory ever afterward retained all of the details, even to the finest dimensions,” [2] of each of his mental experiments. Such a mind is a researcher’s El Dorado, and it has the capability to revolutionize the way scientific research is conducted, and is itself worthy of further research.

3.5 Conjectures: vivid visualization and mental experiments

The fact that we have a brain that is split into two hemispheres with accompanying hemispherical asymmetry has been known since the nineteenth century [17]. Interestingly, though, it is researchers in education, working in the field of children with learning difficulties, who have come up with the classification that some people are predominantly visual thinkers and learners [18, 19]. The term visual thinker or visual-spatial learner is used to describe individuals who think in visual rather than verbal mode. They use the right side of their brain, and may excel in art and music, but are not generally as adept as the general population in left-brain verbal-logical tasks.

3.6 Tesla and other visually gifted people

Tesla was a visual thinker par excellence. He possessed an ability to visualize that is unparallelled in the annals of science. There have been many eminent scientists, mathematicians, artists, and poets who have had unusual abilities to visualize [19]. Among them may be quoted the scientists Michael Faraday and Albert Einstein, the mathematicians Henri Poincaré and Srinivasa Ramanujan, and the mystic poet and painter William Blake. The visual mode of thinking was dominant in each of these people. Einstein, for example, imagined a man riding on a wave of light, and developed his theory of special relativity based on the consequences of this visualization. Faraday was also a visual thinker who liberally illustrated his scientific diaries with diagrams but rarely, if ever, used algebraic equations [19, 20, p 29]. Poincare, one of the founding fathers of topology—the mathematical field that explores what happens to objects as they are deformed, twisted, or stretched, but not torn—was by his own admission a visual thinker. Ramanujan claimed that many of his results appeared in his dreams as ready-made theorems [21, p 66]. William Blake saw visions of realms finer and subtler than this world, while he was, it has been conjectured, in a hallucinatory state of consciousness [22].

What sets Tesla apart from even this distinguished company of gifted people, is that his visualization was conscious and volitional and had verisimilitude. This means that what he visualized was indistinguishable from the real thing being perceived through his eyes, except that, in his case, there was nothing in front of his eyes resembling what he saw. Tesla accepted this gift of his in a matter of fact fashion and even suggested an explanation for what he saw: it was simply the reverse phenomenon of normal vision, in that a mental image in his brain projected a corresponding image on his retina [1]. The
current state of knowledge about human visual perception [23, 24, 25] is such that there is, at present, no definitive explanation for Tesla’s experience.

3.7 Virtual laboratory

The term *gedankenexperiment* or “thought experiment” gained currency, especially after Einstein’s traveller riding on a light wave. However, Tesla’s unique ability to use his mind as a fully equipped, albeit inexpensive laboratory, to conduct the entire design-prototype-test cycle iteratively, gives new meaning to what we *could* mean by thought experiment or mental experiment. Indeed, it is perhaps more accurate to coin the term *virtual laboratory* for describing what Tesla accomplished with his mind and vivid visualization. That is the term we will use hereafter in this paper. The experiments in his virtual laboratory all obeyed the known properties of matter and energy as enshrined in the known laws of physics, and he did not need to tend them until he wished to examine the results.

3.8 The importance of imagination

From the foregoing, we know that Tesla had a vivid imagination—the making of images—harnessed by discipline. It is interesting that in his later years, he extolled the importance of a vivid imagination above that of reason in the following words:

> Our first endeavors are purely instinctive, promptings of an imagination vivid and undisciplined. As we grow older reason asserts itself and we become more and more systematic and designing. But those early impulses, though not immediately productive, are of the greatest moment and may shape our very destinies. Indeed, I feel now that had I understood and cultivated instead of suppressing them, I would have added substantial value to my bequest to the world. But not until I had attained manhood did I realize that I was an inventor. [1]

This resonates with Einstein’s statement, “I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world,” [26].

3.9 Conjectures on the virtual laboratory

Tesla’s intensity of visualization is denied most of us except when we dream. While we dream, we are cut off from sensory input from the outside world. The resulting concentration of mind allows us to visualize vividly in our dreams, but normally we do not have control over what we dream, or indeed even how. Tesla was exceptional in being able to consciously and volitionally conduct what can only be called physically meaningful “dream experiments” in his virtual laboratory, while being fully awake!

It is reasonable to speculate that the capacity of the right brain to imagine, or literally, make images, and the capacity of the left brain to sequence thoughts according to logic are both essential ingredients in the functioning of Tesla’s virtual laboratory. One possible conjecture about Tesla’s mental mode during his virtual laboratory experiments is given below.

3.9.1 Dreams, lucid dreams, and the virtual laboratory
It has generally been believed that wakefulness and sleep are mutually exclusive states of both body and mind. Apart from episodes of absent-mindedness that pass for daydreaming and for abnormal mental states such as hallucinations, it was also the general consensus that dreaming occurred only during the state of sleep. A simplified pictorial relationship between these states is shown in the Venn diagram of Figure 2.

![Figure 2: A simplified picture of the relationship between the states of wakefulness, sleep, and dreaming. Wakefulness and sleep are mutually exclusive. Dreaming only occurs in the sleep state.](image)

Lucid dreaming as a phenomenon was established only in the 1980s. Psychophysiological research has since established that it occurs in Rapid Eye Movement (REM) sleep and is as vivid, if not more vivid than, a normal dream. Nevertheless, the subject who is dreaming is aware that he or she is dreaming and, moreover, can volitionally alter the dream, unlike the regular dreamer [27, 28]. This means that the lucid dreamer occupies a paradoxical state at the borderline between sleep and wakefulness in which the body is essentially in REM sleep, but the mind is aware that it is dreaming and is capable of controlling the dream. Both the dream experience, and the fact that it was a conscious dream, can be recalled during the wakeful state. After the recognition and acceptance of lucid dreaming as a legitimate mental state, we may represent the relationship between wakefulness, sleep, and dreaming by the modified Venn diagram shown in Figure 3.

![Figure 3: Modified, simplified relationship between wakefulness, dreaming, and sleep after the recognition and acceptance of lucid dreaming as a legitimate mental state. Lucid dreamers are mentally aware that they are dreaming and have conscious control over their dreams, while paradoxically, their bodies are asleep.](image)

It is tempting to conjecture that Tesla, working in his virtual laboratory, functioned one level above the lucid dream, in being both physically and mentally awake while inwardly running his mental simulations with all the concentrated power, vividness, automaticity, and verisimilitude of the dreaming mind.

**3.10 Questions: vivid visualization and virtual laboratory**
Tesla’s virtual laboratory is so unusual as to beggar belief. However, Tesla was a scientist and engineer, schooled in accurate observation and respect for objective truth. Moreover, his mode of working in his virtual laboratory, without blueprints and prototypes, confounded and frustrated his co-workers. So we may safely assume that Tesla indeed ran his motor, examined its wear and tear, and then machined it to compensate for that, all in his mind [2, p 58]. This leads to many tantalizing questions, including these:

1. Very simply, how did he do it?
2. What are the prerequisites for an imagination as vivid as Tesla’s?
3. How does one achieve his intensity of visualization while wide awake?
4. What is the peculiar state in which Tesla’s mind operated while he ran his virtual laboratory? Specifically, was Tesla’s mind in a state of daydreaming, hallucination, lucid dreaming, visual thinking, or some as yet unknown mode, during his experiments?
5. Did Tesla simply visualize only the motion or did he visualize the electricity too?
6. How does one visualize electricity?
7. Is precise scientific knowledge a pre-requisite for visualization as in the case of the virtual laboratory? In other words, does a person with such faculties need to know, in addition, the laws of physics and material properties in order to conduct experiments like Tesla?
8. Can the ordinary person acquire the skills needed for a virtual laboratory by suitable training and practice as is done in sport or dance?

These fascinating questions are worthy of exploration, especially since we are so familiar with virtual reality in computer games and simulations nowadays. Using this language, it is clear that Tesla had replicated reality in his mind and was running a virtual laboratory there.

4 Eccentricities of habit and behaviour

Apart from his senses and vivid visualization, Tesla’s body, habits, will power, and social interactions all exhibited anomalies that merit mention and reflection. Although he suffered a mental breakdown at 25, and was prone to nervous exhaustion after long periods without rest, his body exhibited remarkable features. Tesla had a superhuman appetite for work. He was “able to work thirty-eight years almost without a day’s interruption, and [could] find himself still strong and fresh in body and mind” [1]. He also had enormous will power that could not only sustain a punishing schedule but could also permanently banish undesirable habits that he had formed, once he was so convinced. Some of his more notable traits are enumerated below:

1. During his first year at the Polytechnic at Graz, he “regularly started [his] work at three o’clock in the morning and continued until eleven at night, no Sundays or holidays excepted” [1].
2. Tesla excelled at languages and knew English, French, German, Italian and the Slavic dialects [3, p 14].
3. He had a prodigious memory and could store entire logarithmic tables in his mind [3, p 14].
4. He was left-handed but later became ambidextrous [2].
5. He was not good at drawing [1].
6. At the age of fifty-nine, when he slipped on icy ground, he righted himself like a cat while in the air and landed on his feet [1].
7. At sixty-three his body shape and weight had remained unchanged for thirty-five years [1].
8. He was attracted to gambling but gave it up when admonished by his parents. He not only “conquered [his] passion then and there …[but also] …tore it from [his] heart so as not to leave even a trace of desire” [1].
9. He took up smoking, but on realizing that it would ruin his health, he gave it up permanently [1].
10. When Tesla discovered that the innocent cup of coffee he consumed every morning could precipitate heart trouble, he discontinued it by strenuous will [1].

He saw his conquest of bad habits in a different light from most people. He said:

In this way I checked and bridled other habits and passions and have not only preserved my life but derived an immense amount of satisfaction from what most men would consider privation and sacrifice. [1]

One interesting question that arises is whether Tesla’s extraordinary visualization was in any way related to his tremendous will power.

### 4.1 Integrity and moral sense

Tesla was a humanist who desired to use his mind for the freedom of all mankind from the thralldom of matter. He wanted to liberate mankind from drudgery using his magical inventions. While this idealistic vision never left until the last, Tesla was singularly inept in his business dealings. Indeed, one academic who teaches engineering management, and is a lifelong Tesla enthusiast and biographer, has written that he uses Tesla to teach his students how not to run their business affairs [6]. Two incidents that well illustrate not only Tesla’s integrity and moral sense but also his business naïveté are noted below.

Thomas Edison once offered Tesla the then staggering sum of USD 50,000 for improving motor and generator designs. Tesla assiduously applied himself to the changes and gave the Edison company several very profitable patents in the process. When Tesla asked for the USD 50,000, Edison is reported to have replied, “Tesla, you don’t understand our American humor,” and reneged on his promise [7]. Tesla promptly resigned.

The “War of the Currents” [3, chapter 5] between DC and AC, waged between Thomas Edison and George Westinghouse, left both almost bankrupt. Tesla, feeling loyalty and generosity toward his new backer, Westinghouse, did not re-negotiate his patent royalties but rather released Westinghouse altogether. In the process, he lost what would have amounted to almost USD 12,000,000 in royalties [3, p 48–49]. Tragically, toward the end of his life, he was plagued by a chronic shortage of funds.

### 4.2 Tesla as a humanist
Tesla was unambiguous about the place of the inventor in society and of his own role in life. The opening paragraph of his autobiography, which may be called his mission statement, begins thus:

The progressive development of man is vitally dependent on invention. It is the most important product of his creative brain. Its ultimate purpose is the complete mastery of mind over the material world, the harnessing of the forces of nature to human needs. This is the difficult task of the inventor who is often misunderstood and unrewarded. But he finds ample compensation in the pleasing exercises of his powers and in the knowledge of being one of that exceptionally privileged class without whom the race would have long ago perished in the bitter struggle against pitiless elements. [1]

Besides his innumerable inventions, he had also discovered the following, each of which was later “re-discovered” by others who won Nobel Prizes [2, p 166]:

1. Cosmic rays;
2. Artificial radioactivity;
3. Disintegrating beam of electrified particles or atom smasher;
4. Electron microscope; and
5. Very special radiation or X-rays.

Tesla was also the rightful inventor of radio, as established by the US Patent and Trademark Office after his death, although Guglielmo Marconi won the Nobel Prize for it [8]. It is regrettable that Tesla was not only a man ahead of his time, but also one whom society failed to recognize and reward, and whom time has literally forgotten.

### 4.3 Falling asleep

Tesla, being an experimental scientist, was an extremely keen observer. The merit in studying his mind is that he brought his powers of scientific observation to bear on his own mental processes and inner experiences. We therefore have a window into the subjective mind of an extraordinary person, impartially and accurately documented by himself. Tesla fell asleep in a different way than most of us do, and he described it thus:

When I close my eyes I invariably observe first, a background of very dark and uniform blue, not unlike the sky on a clear but starless night. In a few seconds this field becomes animated with innumerable scintillating flakes of green, arranged in several layers and advancing towards me. Then there appears, to the right, a beautiful pattern of two systems of parallel and closely spaced lines, at right angles to one another, in all sorts of colors with yellow-green and gold predominating. Immediately thereafter the lines grow brighter and the whole is thickly sprinkled with dots of twinkling light. This picture moves slowly across the field of vision and in about ten seconds vanishes to the left, leaving behind a ground of rather unpleasant and inert grey which quickly gives way to a billowy sea of clouds, seemingly trying to mould themselves in living shapes. It is curious that I cannot project a form into this grey until the second phase is reached. Every time, before falling asleep, images of persons or objects flit before my view. When I see them I know that I am about to lose consciousness. If they are absent and refuse to come it means a sleepless night. [1]

### 4.4 Idiosyncrasies
Undoubted genius that he was, Tesla also exhibited traits that most of us would consider anomalous, if not downright abnormal. He had an abnormal fear of germs [3, p 263–264] causing him to wash his hands several (but always a multiple of three) times. While dining, he needed eighteen clean linen napkins at the dining table [3, p 1]. He was also extremely fond of pigeons and used to nurse and feed any sick pigeons he found [3]. In his early life, Tesla developed a number of what he called “strange likes, dislikes and habits” [1]. His own account of them is as follows:

During that period I contracted many strange likes, dislikes and habits, some of which I can trace to external impressions while others are unaccountable. I had a violent aversion against the earrings of women but other ornaments, as bracelets, pleased me more or less according to design. The sight of a pearl would almost give me a fit but I was fascinated with the glitter of crystals or objects with sharp edges and plane surfaces. I would not touch the hair of other people except, perhaps, at the point of a revolver. I would get a fever by looking at a peach and if a piece of camphor was anywhere in the house it caused me the keenest discomfort. Even now I am not insensible to some of these upsetting impulses. When I drop little squares of paper in a dish filled with liquid, I always sense a peculiar and awful taste in my mouth. I counted the steps in my walks and calculated the cubical contents of soup plates, coffee cups and pieces of food—otherwise my meal was unenjoyable. All repeated acts or operations I performed had to be divisible by three and if I missed I felt impelled to do it all over again, even if it took hours. [1]

The above quirks of mind and habit suggest that Tesla experienced the following anomalies of mind:

1. obsessive-compulsive disorder;
2. synaesthesia; and
3. high-functioning autism.

His fixation on the number three and having to wash his hands three times, have eighteen napkins on the table during meals, walking around a building thrice before entering it, etc., are all symptomatic of obsessive-compulsive disorder [7]. So, too, his counting the number of steps in his walks, and the cubic capacity of his soup plates and items of food and drink. Tesla’s compulsion with germs and cleanliness may be traced back to periods in his life when he made a trans-Atlantic voyage without his luggage, and when he spent a year digging ditches in the United States to make ends meet. He vowed after these experiences that he would never use a towel twice [6, p 167–168]. One is reminded in this context of how a deeply-felt regret can lead to an obsession, as in the case of Lady Macbeth who famously said, “Here’s the smell of the blood still: all the perfumes of Arabia will not sweeten this little hand,”[Shakespeare, Macbeth, act 5, scene, 1, lines 50–1].

Synaesthesia is a condition in which stimulation of one sensory modality gives rise to a response in another modality [29, 30]. A synaesthete may “taste” a shape for example. It is tempting to speculate that Tesla’s awful taste when dropping paper squares onto a liquid may be symptomatic of synaesthesia. It would also be interesting to explore whether his hyper-acute senses and cross-modal sensory responses influenced each other.
Tesla’s abnormal sensitivity to sounds, his single-minded absorption in what fascinated him, his solitary work habits, his inability to see through the dishonesty of some of his work associates, etc., all suggest that he might have been autistic. However, he had no difficulties with language and, in fact knew Goethe’s *Faust* by heart, along with several Serbian poems. This juxtaposition of some of the strengths found in the autistic with few of their deficiencies, has prompted some to suggest that Tesla probably suffered from high-functioning autism [31] or from Asperger’s syndrome [32, 33], which is a rare condition in which the autistic child is intelligent, highly verbal, and near normal [34]. This would explain both his extraordinary mental faculties and also a number of his mental quirks. The existence of “autistic idiot savants” [34, pp 84–85] who function with super-human excellence in some areas of human endeavour but who are lacking severely in others, suggests that some compensatory mechanism—a sort of zero sum for the total mental capacity—might explain the co-existence of both their “islets of abilities” and concomitant deficits.

### 4.5 Questions: idiosyncrasies

Given that Tesla was unusual in many ways, and could have had what are labelled today as “certain varieties of anomalous experience”, the following questions suggest themselves:

1. Were his abnormalities like synaesthesia and obsessive-compulsive disorder the result of his mental precocity and extraordinary visual sense?
2. Are such conditions a “compensatory” accompaniment of genius?
3. Was Tesla indeed autistic?
4. Could it be that Tesla had both the left and right hemispheres of his brain functioning well above the capacity of normal human beings? (Recall that when the word for an object was spoken he “saw” the object referred to as if it were right in front of his eyes.)
5. Could this have led to some “cross-wiring” of his senses?
6. Could it also have led to the mélange of genius and eccentricity seen in him?

### 5 Tesla’s grandiose claims

Tesla’s plans were always grand. Typical of the visionary, he saw the fruition of his discoveries in his mind and spoke of them even before they had been realized. When commercial or financial imperatives obstructed their realization, he was often sidelined or ridiculed by the scientific establishment. Yet, the very things he envisaged then are realities in our present age of semiconductors, computers, and the Internet. To appreciate just how prophetic his vision was, let us look at just one example: his “World-System”. In the vocabulary of Tesla’s day, this system would be capable of:

1. The inter-connection of the existing telegraph exchanges or offices all over the world;
2. The establishment of a secret and non-interferable government telegraph service;
3. The inter-connection of all the present telephone exchanges or offices on the Globe;
4. The universal distribution of general news, by telegraph or telephone, in connection with the Press;
5. The establishment of such a ‘World-System’ of intelligence transmission for exclusive private use;
6. The inter-connection and operation of all stock tickers of the world;
7. The establishment of a ‘World-System’ of musical distribution, etc.;
8. The universal registration of time by cheap clocks indicating the hour with astronomical precision and requiring no attention whatever;
9. The world transmission of typed or handwritten characters, letters, checks, etc.;
10. The establishment of a universal marine service enabling the navigators of all ships to steer perfectly without compass, to determine the exact location, hour and speed, to prevent collisions and disasters, etc.;
11. The inauguration of a system of world-printing on land and sea; and
12. The world reproduction of photographic pictures and all kinds of drawings or records. [1]

Grandiose claims they may have been in his time. Today, the world-mind has enlarged beyond measure compared to the pre-transistor days in which Tesla lived. It is to his great credit that in a world of condensers and coils, he could visualize what electricity was capable of, in the service of mankind.

In his later years, he formulated grand plans to use lightning to generate artificial rain to turn deserts into gardens [1]. Another of Tesla’s pet projects was the wireless transmission of free electrical energy from which all mankind could benefit [35]. This was in keeping with his mission statement. It was also consistent with the fact the earth receives its sum total of energy from the sun in precisely the same fashion. Yet, such grandiose projects and claims led to the marginalization of Tesla as a force in science. Are his claims of tapping an infinite energy source all around us worth re-investigation in these times when global warming and the finitude of fossil fuels is forcing a re-examination of all energy options?

5.1 Tesla and Swami Vivekananda

Ideas about unlimited, free energy might have found resonance with Tesla after his meeting with the famous Hindu monk, Swami Vivekananda, who visited the United States in the 1890s [8, 36, 37]. It is held that Tesla met the Swami in 1895–6 and that he was receptive to the ideas expressed in the Sanskrit language of Hindu cosmology about a universal energy, called prāṇa and the vehicle for it, called ākāśa, literally the medium for radiance. The exposure to the idea that everything is floating in a sea of universal prāṇa must have taken hold in his fertile imagination and given rise to claims about the possibility of free energy from the capture of solar “cosmic rays” that could be used to drive machines. His biographer O’Neill states that in an unpublished article entitled “Man’s Greatest Achievement”, Tesla speaks of mankind in general, saying [2, p 270]:

Long ago, he recognized that all perceptible matter comes from a primary substance, or tenuity beyond conception, filling all space, the Akasa or luminiferous ether, which is acted upon by the life-giving Prana or creative force, calling into existence, in never ending cycles, all things and phenomena. The primary substance, thrown into infinitesimal whirls of prodigious velocity, becomes gross matter; the force subsiding, the motion ceases, and matter disappears, reverting to the primary substance.
Can Man control this grandest, most awe-inspiring of all processes in nature? Can he harness her inexhaustible energies to perform all their functions to his bidding, more still to cause them to operate simply by the force of his will?

The fact that Tesla, who did not know Sanskrit, used the words prāṇa and ākāśa lends support to the claim that he did indeed meet Swami Vivekananda. Tesla’s expression “tenuity beyond conception” corresponds perfectly with the statement “ta ākāśe na vidyante” meaning ākāśa is imperceptible [38, p 92], showing Tesla’s ability to grasp abstruse philosophical points. Indeed, he did expound on philosophy, and was in that sense a well-rounded scholar [39].

Post-Einsteinian physics has not found a need for ākāśa or the luminiferous ether, but there is a need for something, regardless of label. Indeed, in a recent article on the ether, it has been observed that “Physicists appear to need an ether on which to load all the properties of the physical world they cannot otherwise explain. Ether, alias the vacuum, exists. Void is anything but nothing” [40].

5.2 Tesla’s pigeon

Although possessed of mental abilities that could almost be termed psychic, Tesla did not give vent to the expression of his spiritual side [2]. Indeed, when once approached by a team of engineers to join a psychological society for investigating psychic phenomena, Tesla almost threw them out [1].

With regard to his neglected spiritual side, Tesla’s pigeon fixation affords an interesting story [3]. Tesla loved one particular female pigeon, almost as he would love a human being. He recalled that one night, as he was lying on his bed in the dark, this pigeon flew in through the open window, as if to deliver a message. He looked at her and realized that she had come to tell him she was dying. As he looked at her, Tesla said, “there came a light from her eyes—two powerful beams of light”. He reaffirmed, “Yes, it was a real light, a powerful, dazzling, blinding light, a light more intense than I had ever produced by the most powerful lamps in my laboratory” [3, p 229]. When that pigeon died, Tesla “knew” that his life’s work was finished.

Although Tesla never publicly gave expression to his religious or spiritual beliefs, this pigeon episode inevitably calls for comparison with the biblical account of the baptism of Jesus by John the Baptist: “…and he saw the Spirit of God descending like a dove, and lighting upon him…” [Matthew 3:17].

6 Bucke’s hypothesis on human mental evolution

The medical doctor, Richard Maurice Bucke², writing at the beginning of the twentieth century, advanced the radical hypothesis that evolution also applied to the human mind [10]. Although he used the word “evolution”, Bucke did not imply any particular engine, like Darwinian natural selection, for driving mental evolution, but rather asserted blandly “that growth, evolution, development, …has …always gone on, is going on now, and …will always go on” [10, p 61].
As a lead-in to his idea of mental evolution, Bucke proposed, among other things, that man’s sense of colour, sense of fragrance, and musical sense had all developed over time to their present state. Accordingly, he proposed that human colour vision was a recent evolutionary development. He suggested that as sensory perception evolved, the vocabulary of languages kept pace to deal with this increasing sophistication. Tracking the gradual development of the words for different colours in ancient languages and literature, he suggested that the perception and recognition of colours kept pace with each other according to the tree illustrated in Figure 4. Bucke claimed that:

> When a new faculty appears in a race it will be found, in the very beginning, in one individual of that race; later it will be found in a few individuals; after a further time in a larger percentage of the members of that race; still later in half the members; and so on, until, after thousands of generations, an individual who misses having the faculty is regarded as a monstrosity. [10, p 52]

![Figure 4: Evolution of colour perception in human beings as conjectured by R M Bucke. This diagram is adapted from Bucke [10, p 36]. Time increases as one moves right. The circled colours were the ones newly recognized at any particular period. So, the progression of newly recognized colours was red/black, followed by yellow/green and later by white/blue. Bucke cites literary and scientific evidence in support of his conjecture. While his scientific arguments have now been supplanted, the literary arguments are still persuasive.](image)

Extrapolating from his suggested hypothetical development of colour vision, etc., over time, Bucke postulated that the human mind also evolved with time. He distinguished three progressive states of consciousness so:

1. Simple consciousness that is possessed by the higher animals and man by which they are aware of their surroundings and also of their own bodies as integrated entities;
2. Self consciousness which is not present in animals, but only in man, whereby man becomes aware of himself as a distinct entity apart from the rest of the universe, and which allows him to treat his own mental states as objects of consciousness, and also allows communication by language; and
3. Cosmic consciousness which includes simple and self consciousness, but which in addition allows “a consciousness of the cosmos, that is, of the life and order of the universe” [10, p 3] and “an intellectual enlightenment or illumination
which alone would place the individual on a new plane of existence—would make him almost a member of a new species” [10, p 3]. Bucke stated that the burden of his book was to expound the nature of this exalted state and identify some of its exemplars.

While there have been many extraordinary spiritual leaders of humankind with superior mental attributes, Tesla’s phenomenal mental abilities present one of the most prominent examples of such abilities in a man or woman of science. Whether or not Tesla possessed “cosmic consciousness” in accordance with Bucke’s definition, we may justifiably ask whether Tesla possessed a more evolved mind than the ordinary human being. Or more precisely, was Tesla a representative from our future, in which those possessing his faculties would be more numerous than today? It is a tantalizing question that may have no clear cut answers.

7 Conclusions

Like Icarus, Tesla sought the freedom of flight. Like Prometheus, Tesla wrested the subtle fire of electricity from the realm of the invisible and brought it down into the world of mortals. Like Zeus, he wielded the thunderbolt by creating lightning artificially. Like Archimedes of Syracuse, his thoughts were always on a grand scale and he was not only the theoretical mathematical physicist but also the practical engineer-inventor.

Tesla was larger than life and greater than most of his fellow human beings. He excelled in his intellect, power of will and visualization, and his moral sense. He was unambiguous in his personal mission statement about the social responsibility of the inventor-scientist as one who ameliorates the life of his fellow human beings. He held that the pleasure of discovery and invention was its own reward. He embraced the insights that came to him through non-rational processes of thought. Perhaps, he exercised more symmetrically and to a greater degree than most people, both the right and left hemispheres of his brain.

One rather sad, recurring theme in the biographies of Tesla is that he was somehow a misfit either in the society in which he lived and worked, or the times in which his life was enacted. Margaret Cheney’s biography, Tesla: Man Out of Time, clearly shows this in its very title. As does also the subtitle of Lomas’s book [6], Nikola Tesla, Forgotten Genius of Electricity. Do these titles hold the key to Tesla’s mystery? Was Tesla from our future?

The most important contribution of Tesla may not be the alternating current grid, or the induction motor, or any of his other electrical inventions. It may simply be the fact that he was a very unusual human being with remarkable mental powers that most of us can only call incredible or legendary. How did he come by them? Were his abilities the result of some form of compensation as in the autistic idiot savant, or was it simply that Tesla was a man from our future who had torn the veil of time to visit us and give us a glimpse of the future capabilities of humankind?

8 Acknowledgements
References


MENTAL ACCESS WINDOW

by Jack Houck

TREAT VI Conference - Virginia Beach, Virginia

April 27 May 1, 1994

Abstract

What if the ability to do remote viewing, PK, and other high performance mental techniques could be induced with high-tech means? There is some evidence that there is a mental access window (MAW) when the predominant frequency of an individual's electroencephalogram (EEG) is 7.81 to 7.83 Hz. This is the same frequency range in which slight oscillations in the earth's magnetic field occur, known as "Schumann Resonance". (Interestingly, this frequency also corresponds to REM sleep and hypnogogic imagery.) Houck first learned of the ideas from Dr. Bob Beck when he purchased a simple EEG biofeedback unit from Beck. The unit provides auditory feedback of brain activity to the user. Beck suggested that they make a recording of an input signal of exactly 7.81 Hz. Houck listened to the EEG unit attached to his head in one ear while simultaneously listening to the 7.81 Hz (using frequency modulation, the EEG signal is combined with a 2000 Hz tone so it can be heard) recording in the other ear. After a few minutes of relaxing, the two sounds became very similar, and then --- a full blown out-of-body experience. Of the 45 people who have tried this equipment, approximately one-half have reported either a full blown or partial out-of-body experience. This experience led to evaluating the frequency spectrum of people's EEGs, and has resulted in some correlations with the type of individual. For example, psychics and geniuses have strong components of their EEG frequency in the MAW, even in their awake state.

Introduction

For over twenty years, I have been interested in "Remote Viewing". Even though this phenomenon has been around since the beginning of man, only since the early 1970's has it been researched for training and application, originally by Targ and Puthoff at the Stanford Research Institute (SRI) International in Menlo Park, California\(^1\). They coined the term "Remote Viewing" in an attempt to describe an individual's ability to have mental access to remote places and "see" what was there. In the metaphysical community this ability is known as clairvoyance.

In the late 1970's, I began to conduct experiments in an attempt to replicate some of the SRI experiments. I was sufficiently impressed by what I observed during these experiments that I concluded that humans really could send their minds out to remote places and not only "see", but all other body senses also have access to information at that remote location. This is why some research laboratories began calling the phenomenon "Remote Perception." In 1980, I wrote a paper\(^2\) to document my thoughts about how, conceptually, the human
brain/mind might be able to access information at locations where the viewer had never been. Some of the key points are listed below:

a. Each person has two complete sets of senses. One set is the familiar physical senses (vision, hearing, feeling, smelling, and taste). The other set I postulate is associated with the mind and accesses information which is not necessarily local to the physical body. The brain processes both sets of senses, as shown in Figure 1.

![Fig. 1. Brain/Mind access to remote information.](image1)

b. There is a central storage system where all information is stored, both past and possible future events. I call this the Space Time Unit (STU). The original acronym was intended to be funny --- you know, where everything is. Of course, engineers are not known for being great spellers, especially this one. The STU is probably located in another dimension, other than our normal space-time dimensions.

![Fig. 2. Model of human brain interaction with senses.](image2)
c. When the mind accesses a remote location, it scans in time until it locks onto a "peak emotional event" at that location. The information at that place and time is then available in all sensory detail to the individual because it is being processed by the brain. It was this idea that led to the metal bending experiments which have become known as PK Parties\(^3\). Figure 2 is an attempt to display the type of feedback loop that would have to occur, with the brain constantly transmitting information into the STU and constantly receiving information both from the physical senses and the STU. The figure shows the information being added in each sensory type (body sensory signals represented by \(S_B\)) where \(i\) is 1 through 5 for each of the senses, and external sensory signals represented by \(S_E\)) and processed by the appropriate cortex of the brain. The processed sensory signal \((S_i)\) to brain background noise \((N)\) is critical to the clarity with which a person perceives that sensory information. The background brain noise seems to be a function of the total brain processing load (the slow senses like taste and smell, do not contribute much background noise whereas hearing and vision require much more processing which results in more background noise). With this model, memory is stored in the STU. Normally, the sensory signals from an individual's physical senses are so strong, they overwhelm the signals from the external senses, and the individual is unaware of those signals. However, when the signals from the physical body are reduced to the point where the external signals are completely dominant, then the person has a full blown out-of-body experience or a dream which can combine data from memory and other information in the STU. The key point is that the brain is still processing the information, even though the individuals think they are at some remote location during an out-of-body experience.

While parameters for helping people learn how to do Remote Viewing are somewhat understood (e.g., deep relaxation, quiet surroundings, starting by accessing with the slow senses like smell), the transfer mechanism for the information access and the conditions which promote the brain processing of the remote senses are not well understood. This paper is an accumulation of my thoughts on a possible correlation of an individual's electroencephalograph (EEG) characteristics and the earth's magnetic field oscillations, known as Schumann resonance. Helping individuals to achieve their EEG at the proper frequency should then allow them to have better mental access to the STU, which in turn should improve their performance on any mental task.

**Schumann Resonance**

In 1952, a German mathematician, Schumann, postulated that the lightening bolts throughout the earth stimulate the cavity between the earth surface and ionosphere to resonate at extremely low frequencies (ELF), causing the earth's magnetic field to oscillate at these frequencies\(^4\). He suggested that these oscillations would be less than 11 Hz. The magnetic detection equipment available at that time was not sufficiently sensitive to measure these oscillations.
A refinement on his postulation was published in 1957\(^5\). In 1961 the National Bureau of Standards actually measured these magnetic field oscillations\(^6\), as shown in Figure 3. The eleven samples shown have the associated date shown in the figure. There were two detection coils, one with the axis pointed north/south (N-S) and the other pointed east/west (E-W). Soon after, additional measurements were made and summarized in a frequency presentation, shown in Figure 4, as presented in a report done for the CIA\(^7\). Wortz suggested the primary Schumann oscillation was at 7.8 Hz, with harmonics at 14.1 and 20.3 Hz. Dr. Robert Beck observed that the Schumann resonances, often called
waves, looked very much like the EEGs of humans. He also averaged his Schuman resonance measurements and compared these to EEG measurements taken from shamans, healers, Indian yogis, and psychics, and concluded that the primary mental access window (MAW) was between 7.81 and 7.83 Hz. I thought these researchers were indicating that the radiation caused by the lightning was travelling around the earth between the earth's surface and the ionosphere at the speed of light 7.81 to 7.83 times per second, depending on whether the path was around the poles or the equator, respectively. However, my calculations indicate it would be 7.49 to 7.51 Hz, if that was the correct model. Actually, the height of the ionosphere is constantly changing and these oscillations are affected by the sun spot activity as well as magnetic storms. The general idea is that as long as the earth has been evolving, all things on the earth's surface have been exposed to these magnetic field oscillations and possibly, when an individual's EEG becomes the same frequency as the current Schumann resonance, his or her brain synchronizes with these oscillations and then the person's mind can easily access information throughout the world.

**EEG Measurements**

It was Dr. Beck who familiarized me with these ideas about the Schumann waves. I purchased an EEG biofeedback unit which he had designed and built. This particular unit has the following characteristics:

a. Very small and thus very portable.

b. Battery operated only.

c. Primary feedback is auditory; the EEG signal is superimposed on a 2,000 Hz tone using a frequency modulation technique so that the ear can hear the oscillations. The signal amplitude is represented by a variation in the frequency spread of the superimposed signal, thus, it sounds more pronounced. The ear can quickly be trained to recognize the frequency region (alpha, beta, theta) and the amplitude of the signal. The tone frequency range was chosen such that a standard cassette tape recorder could be used to record the data.

d. An additional output source is provided so the actual EEG signal can be displayed on a medical oscilloscope (i.e., isolated from the house current).

e. The input electrodes are sufficiently sensitive so that only salt water need be used to obtain a good electrical connection with the human head.
f. The unit has one channel with the electrodes placed on the head centerline (one electrode in the center of the forehead and the other electrode in the center of the back of the head, frontal to occipital- mid line). This provides an average EEG signal between the right and left hemispheres. When both hemispheres are synchronized (in phase), the EEG signal is high. This helps the biofeedback trainees to train themselves to synchronize their brain hemispheres. A schematic of Beck's biofeedback EEG unit is shown in Figure 5.

The definition I use for the frequencies corresponding to the various brain wave states are shown in the following table:

<table>
<thead>
<tr>
<th>Frequency Band (Hz)</th>
<th>Brain Wave State</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4 Delta (Δ)</td>
<td></td>
</tr>
<tr>
<td>4-8 Theta (θ)</td>
<td></td>
</tr>
<tr>
<td>8-14 Alpha (α)</td>
<td></td>
</tr>
<tr>
<td>14 - and higher Beta (β)</td>
<td></td>
</tr>
</tbody>
</table>

My personal experience using Beck's EEG biofeedback unit for three months, approximately 20 minutes per day, was that I developed the ability to relax quickly and to have some control over the frequency of my brain waves. I also discovered that it was a way for me to learn how to meditate, whereas otherwise I seemed to never find the time.

About that time my son had to do an eleventh grade physiology project. He wanted to do an experiment measuring people’s EEGs. In order to present the data, I purchased an analog-to-digital (A/D) board for my Apple 11+ home computer. We set up a system where he would record the brain waves of the subjects in his experiments on cassette tape. We would then feed that data into a discriminator (provided by Beck) which would remove the 2,000 Hz tone from
the EEG data. We fed this data through the A/D converter in the computer. We wrote some software which would take 20 seconds of the digitized EEG data and perform a 256 point fast Fourier transform (FFT) on each second of data, and present the results in a three-dimensional graphic display, which could be printed as shown in Figure 6.

![Figure 6 3-dimensional presentation of data from signal processing equipment](image)

Fig. 6. 3-dimensional presentation of data from signal processing equipment. The input signal for this plot was a single sine wave at 7.81 Hz. This shows that the processing system is very clean and free of external noise. Slight harmonics of the input frequency do show up in the figure. The three axes of the plot are frequency, amplitude (i.e., the amount of the total frequency components being produced at each frequency), and time with the FFT of the first second being shown in front and the FFT of the 20th second being shown toward the back in the plane of the frequency and amplitude axes. That first Apple based system took approximately 30 minutes of computations to prepare one plot. Today, my 66 MHz IBM computer system presents this data in almost real time. A schematic of the EEG frequency processing equipment with Beck's EEG biofeedback equipment is shown in Figure 7.
Fig. 7. EEG frequency display system.

Over the years, I have had the opportunity to measure the EEG patterns of many interesting people. I presented some of these data at the First Archaeus Congress in 1986. Some interesting correlations seem to have emerged between these brain wave patterns and the type of individual. Several typical examples are shown in the following figures:
Figure 8 - EEG pattern of the author, typical of a very focused, trainer type individual. Note the single frequency ridge with a very narrow frequency bandwidth.

Figure 9 - EEG pattern of a skilled psychic individual. Note the extreme spread of simultaneous frequencies, with most occurring in the theta and alpha regions.
Figure 10 - EEG pattern of a millionaire. Note the apparent predominance of two simultaneous frequencies, one around 8 Hz and the other in the alpha region. This same dual frequency pattern appears on other millionaires. Is this pattern trainable?

Figure 11 - EEG pattern of a bright teenager. Note the large amount of very low frequency activity, perhaps due to the continuing development of the brain.
So-called normal people have many more high frequency components in their EEG pattern. The results from this limited study suggest that those individuals who seem to have better access to acquiring information outside of their physical body have strong components of their EEG frequencies in the region of 8 Hz, amazingly close to the average Schumann resonance.
Nighttime Brain Activity

There has been extensive research on sleep and dreaming during the past thirty years. While I am no expert on these subjects, let me suggest how these areas may interact with the idea of there being a MAW. First, in Figure 13, an idealized history of an individual's night time EEG frequency is postulated. This would be from an individual who has a narrow band EEG frequency so that a single frequency as a function of time can be discussed. The time in this figure starts as a person in an excited state begins to go to sleep. As the person relaxes, the brain wave frequency begins to decrease, and eventually the person loses consciousness (falls asleep). This probably occurs around 9 Hz.

As the brain wave frequency continues to drop, it reaches the point where the first dream occurs, usually around 8 Hz. It could be at the time the brain waves become coincident with the Schuman resonance or move into the MAW. This is also when rapid eye movement (REM) occurs, as well as hynogonic imagery. (Are we watching what we are accessing?) As mentioned earlier, dreams may combine data from our own memory with data accessed from remote locations, as is the case when data from memory and local objects is sometimes accidentally combined with the intended remote site during remote viewing.
As our hypothetical sleeping person in Figure 13 continues through the night, the EEG frequency continues to decrease through the first "deep sleep" cycle. When it again returns to approximately 8 Hz, the person probably has another dream. This Circadian rhythm continues through the night, but decreases in depth as morning approaches. For people whose threshold for consciousness is close to their MAW, the period of light sleep will produce an in-and-out of sleep state or hypnopompic imagery where accessing information is optimized. The should be a time for getting good ideas, remote travel, remote viewing, and remote healing.

Fig. 14. Technique for inducing out-of-body experiences.

Mental State Induction

Shortly after I did the EEG biofeedback training, Dr. Bob Beck suggested that we make an audio tape of what a person's EEG would sound like on his equipment when we input a pure sine wave at 7.81 Hz. His contribution was to suggest listening to this sound in one ear and listen to one's own brain waves in the other ear and see what would happen if the sounds became the same. A schematic of this equipment setup is shown in Figure 14. One day I decided to try this. With the biofeedback training, I was able to move my EEG frequency to the same frequency being produced by the tape recording. At the time, it seemed like I could even tell when the two sounds became like one --- in phase. At that moment, I found myself floating above a tennis court watching a tennis
match as part of a full-blown out-of-body experience. This seemed to go on for some time before I had the sensation that the tennis ball was about to hit me in the face. I jumped, and instantly found myself in my own body, having jumped out of the chair I had been sitting in, with all the wires hanging from my head.

Whenever I have described this experience, people want to try it themselves. So, over the years, there have been about 45 people who have tried this system. None of them has EEG biofeedback training. Most have had fairly broadband frequency spectrums in their EEG. They would listen to 20 minutes of sounds being frequency modulated by 7.81 Hz from this cassette tape. About half of them have reported some degree of out-of-body experience. A few have fallen asleep. Others think it is "Interesting". I have not made any attempt to further test these people. However, it is my opinion that this sound has the effect of lowering people's brain wave frequencies and, for some, induced their EEG brain waves into the MAW. There are reported to be other techniques for inducing selective brain wave frequencies, such as flashing lights, other audio techniques (e.g., Monroe's Hemisync), and even electromagnetic "pacers".

**Summary**

Many studies could be done in these areas, if funding were available, to determine if Remote Viewing could be facilitated, general intelligence could be improved, and remote PK and healing could be enhanced. My contention is that there is great potential to enhance any mind/brain application by improving our understanding of the relationship between the earth's magnetic field oscillations (Schumann resonance) and the apparent mental access window. This understanding could then be used to develop techniques that move our EEGs into that window. I recommend research on the use of sensitive measurement equipment to determine the current local Schumann resonance prior to the entrainment of the individual's EEG brain to that frequency. I also recommend research to determine how much of the frequency bandwidth of an individual's brain waves must be in the mental access window for that person to achieve significant remote mental access.

**References**


Bioelectromagnetic Healing, its History and a Rationale for its Use

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Proceedings of the Whole Person Healing Conference, Bethesda, MD, 2003

Abstract

Bioelectromagnetics (BEMs) is the study of the effect of electromagnetic fields on biological systems. 1 Though electromagnetic fields have sometimes been associated with potential for harm to the body, there are many BEM instruments and devices re-emerging in the 21st century, based on high voltage Tesla coils, that apparently bring beneficial health improvements to human organisms. The Tesla coil class of therapy devices constitute pulsed electromagnetic fields (PEMF) that deliver broadband, wide spectrum, nonthermal photons and electrons deep into biological tissue. Electromedicine or electromagnetic healing are the terms applied to such developments in the ELF, RF, IR, visible or UV band. With short term, non-contacting exposures of several minutes at a time, such high voltage Tesla PEMF devices may represent the ideal, noninvasive therapy of the future, accompanied by a surprising lack of harmful side effects. A biophysical rationale for the benefits of BEM healing a wide variety of illnesses including cancer, proposes a correlation between a bioelectromagnetically restored transmembrane potential, and the electron transport across cell membranes by electroporation, with normal cell metabolism and immune system enhancement. The century-long historical record of these devices is also traced, revealing questionable behavior from the medical and public health institutions toward such remarkable innovations. This report also reviews the highlights of several BEM inventions but does not attempt to present an exhaustive nor comprehensive review of bioelectromagnetic healing devices.

History of Bioelectromagnetic Healing

Historically, as far back as 1890, the American Electro-Therapeutic Association conducted annual conferences on the therapeutic use of electricity and electrical devices by physicians on ailing patients. Some involved current flow through the patient, while others were electrically powered devices. At first, only direct current (DC) devices were utilized in the medical doctor’s office for relieving pain and vibrating female patients who were routinely diagnosed with “hysteria.”

Nikola Tesla

In 1895, the Niagara Falls Power Company opened for the first time and within a year, sent alternating current (AC) to Buffalo, NY, twenty-five miles away, thanks to Nikola Tesla AC generators. Cities throughout the world followed suit and made commercial AC power available to the general public, even miles from the power
generating station. As a result, Tesla’s high voltage coil devices, which were powered by AC, started to become widely known and applied.

In 1898, Tesla published a paper that he read at the eighth annual meeting of the American Electro-Therapeutic Association in Buffalo, NY entitled, “High Frequency Oscillators for Electro-Therapeutic and Other Purposes.” He states that “One of the early observed and remarkable features of the high frequency currents, and one which was chiefly of interest to the physician, was their apparent harmlessness which made it possible to pass relatively great amounts of electrical energy through the body of a person without causing pain or serious discomfort.” Coils up to three feet in diameter were used for magnetically treating the body without contact, though ten to a hundred thousand volts were present “between the first and last turn.” Preferably, Tesla describes using spheres of brass covered with two inches of insulating wax for contacting the patient, while unpleasant shocks were prevented. Tesla concludes correctly that bodily “tissues are condensers” in the 1898 paper, which is the basic component (dielectric) for an equivalent circuit only recently developed for the human body. In fact, the relative permittivity for tissue at any frequency from ELF (10 Hz-100 Hz) through RF (10 kHz–100 MHz) exceeds most commercially available dielectrics on the market. This unique property of the human body indicates an inherent adaptation and perhaps innate compatibility toward the presence of high voltage electric fields, probably due to the high transmembrane potential already present in cellular tissue. Tesla also indicates that the after-effect from his coil treatment “was certainly beneficial” but that an hour exposure was too strong to be used frequently. This has been found to be still true today with the Tesla coil therapy devices. On September 6, 1932, at a seminar presented by the American Congress of Physical Therapy, held in New York, Dr. Gustave Kolischer announced: “Tesla’s high-frequency electrical currents are bringing about highly beneficial results in dealing with cancer, surpassing anything that could be accomplished with ordinary surgery.”

Alexander Gurvich

In 1922, the Russian doctor and histologist Alexander (Gurwitsch) Gurvich (1874-1954) and his wife discovered that living cells separated by quartz glass were able to communicate vital-cell information. Numerous experiments suggested that this information was transmitted by invisible light waves in a UV frequency spectrum passed by quartz and stopped by window glass. Dr. Gurvich coined the phrase “mitogenic” “mitotic” wave since it was observed during enzymatic reactions and mitosis. “Gurvich determined that muscle tissue, cornea, blood and nerves are all transmitters of this special energy.” His work is the first documented evidence of “biophotons,” coherent light emitted by animal and plant cells, and became the basis for the design of later bioelectromagnetic therapy devices. It was not until the early 1960’s that Leningrad State University succeeded in capturing the mitogenic rays with sensitive photomultipliers.

Georges Lakhovsky

In 1925, Georges Lakhovsky published a paper with the explicit title of “Curing Cancer with Ultra Radio Frequencies” in Radio News. His expressed philosophy was
that “the amplitude of cell oscillations must reach a certain value, in order that the organism be strong enough to repulse the destructive vibrations from certain microbes.” He goes on to say, “The remedy in my opinion, is not to kill the microbes in contact with the healthy cells but to reinforce the oscillations of the cell either directly by reinforcing the radio activity of the blood or in producing on the cells a direct action by means of the proper rays.” Lakhovsky’s Radio-Cellulo-Oscillator (RCO) produced low frequency ELF all the way through gigahertz radiowaves with lots of “extremely short harmonics.” He favored such a wide bandwidth device so that, “The cells with very weak vibrations, when placed in the field of multiple vibrations, finds its own frequency and starts again to oscillate normally through the phenomenon of resonance.” As a result, Lakhovsky’s RCO is now more often called MWO (multiple wave oscillator) for these reasons. The MWO uses a Tesla coil and special antenna with concentric rings that induce multiple sparks between them. Details can be found in his US patent #1,962,565 and the compact, portable, screw-in-lightbulb-style-vacuum-tube upgrades seen in his US patent #2,351,055. Lakhovsky’s article and patents can be found on line at: http://www.rexresearch.com/lakhov/lakhusps.htm. His book, The Secret of Life was first published in English in 1939. In 1949, a review of Lakhovsky’s work was published as Waves That Heal by Mark Clement. Besides this technical information, the life of Lakhovsky is a study in suppression and summarized below in a paper by Chris Bird:

The first man I will mention today is the Russian-born Frenchman, Georges Lakhovsky. I learned only yesterday that Lakhovsky seems to have been an associate, or knew, Nikola Tesla. I had not known that and from the point of view of the history of energy medicine, it's a very interesting thing. At any rate, Georges Lakhovsky began to experiment with what he called a "multiwave oscillator." (In the Library of Congress there are some ten books written by Lakhovsky, all in French.)

This multiwave oscillator (MWO) put out a very broad spectrum of electromagnetic frequencies. The theory, as propounded by Lakhovsky, was that each cell in the body of an organism—be it a plant, an animal, or a human being—is itself a little radio receiver and works on its own special little frequency. Each cell, in addition to being tissue, in addition to being biology, is also electricity. On that theory, he held that pathology was a not matter of biological concern or intervention, but one of electrical concern and intervention. He theorized that from the bath of electrical frequencies put out by the multiwave oscillator, each cell individually could and would select that frequency which it most needed to restore its equilibrium.

So he began to experiment not with animals or human beings, but with geraniums. These were geraniums which had cancers—plants get cancers too. And, lo and behold, the geraniums were cured of their cancers; which simply began to fall off since they are external in the case of geraniums. The geraniums would just shed the diseased tissues when exposed to the MWO. Lakhovsky then went on to do work on animals and human beings and his work was picked up by doctors in six or seven countries, among them Italy, Sweden and Brazil. Finally, because he was on the "wanted" list of the Nazis, he was smuggled out of France and came to New York during the war, where he worked with a urologist. The record of his treatment of degenerative disease, with what amounts to an early "energy-medicine" device, was remarkable. But the work had to be done in secret because orthodox medicine did not favor this device, and its power, associated with that of the FDA and the AMA and other "control organizations," kept the MWO underground.
The Lakhovsky device is a very effective one. I'm not going to say that it's 100% effective because I don't think any device is, but it is way up there. Georges Lakhovsky died in 1944 or 1945.  

Royal Raymond Rife

In 1934, the University of Southern California appointed a Special Medical Research Committee to study 16 terminal cancer patients from Pasadena County Hospital that would be treated with mitogenic impulse-wave technology, developed by Royal Raymond Rife. After four months the Medical Research Committee reported that all 16 of the formerly-terminal patients appeared cured.

Rife’s high voltage gas tube device was designed, with the aid of his unique microscope, by experimentally witnessing the effects on microbes and bacteria, finding what he believed were the particular frequencies that resonated with their destruction. “In 1938, Rife made his most public announcement. In a two-part article written by Newall Jones of the San Diego Evening Tribune (May 6 & 11), Rife said, ‘We do not wish at this time to claim that we have ‘cured’ cancer, or any other disease, for that matter. But we can say that these waves, or this ray, as the frequencies might be called, have been shown to possess the power of devitalizing disease organisms, of “killing” them, when tuned to an exact wave length, or frequency, for each organism. This applies to the organisms both in their free state and, with certain exceptions, when they are in living tissues.’”

“He had the backing in his day - this was in the 1930’s - of such eminent people as Kendall, a professor of pathology at Northwestern University and Millbank Johnson, M.D., who was on his board, along with many other medical men, when he began to treat people with this new ‘ray emitter.’… There were articles written on the Rife technique… in the Journal for the Medical Society of California and other medical journals. Suddenly, Rife came under the glassy eye of Morris Fishbein of the AMA and things began to happen very quickly. Rife was put on trial for having invented a ‘phony’ medical cure. The trial lasted a long time.”

In 1953, Rife published his cancer report in book form, History of the Development of a Successful Treatment for Cancer and Other Virus, Bacteria and Fungi. A turning point occurred in 1958, when the State of California Public Health Department conducted a hearing which ordered the testing of Rife’s Frequency Instrument. The Palo Alto Detection Lab, the Kalbfeld Lab, the UCLA Medical Lab, and the San Diego Testing Lab all participated in the evaluation procedure. “All reported that it was safe to use. Nevertheless, the AMA Board, under Dr. Malcolm Merrill, the Director of Public Health, declared it unsafe and banned it from the market.”

In 1961, after a trial with an AMA doctor as the foreman of the jury, John F. Crane, the new owner of the Rife Virus Microscope Institute, spent three years in jail, ostensibly for using the Frequency Instrument on people, though no specific criminal intent had been proven. In 1965, he attempted to obtain approval from the California Board of Public Health for use of the Frequency Instrument. “On November 17, 1965, the Department of Public Health replied that Crane had not shown that the device was safe or ‘effective in use.’”

From 1968 to 1983, Dr. Livingston-Wheeler treated approximately 10,000 patients with the Rife Frequency Instrument, at her University of Southern California clinic, with an 80% success rate. In 1972, Dr. Livingston-Wheeler published Cancer: A New
Breakthrough in which she “condemned the National Cancer Institute for its misuse of money [$500 million in 13 years], the corrupt handling of public health responsibilities, and its use of people [100,000 cancer patients] as guinea pigs for a ‘surgery-radiation-chemotherapy’ program dictated by special interests.”¹⁶ Her last book on The Conquest of Cancer was published in 1984 in which she celebrates the European acceptance of the Rife discoveries but complains about the situation in the U.S.

All these distinguished scientist, back in 1958, had been carrying on significant research in the biological and immunological treatment of cancer for years. It is still only now that the United States orthodoxy is beginning to catch up. Because of the suppressive actions of the American Cancer Society, the American Medical Association, and the Food and Drug Administration, our people have not had the advantage of the European research.

This work has been ignored because certain powerful individuals backed by large monetary grants can become the dictators of research and suppress all work that does not promote their interests or that may present a threat to their prestige.¹⁷

Rife died in 1971, mostly of a broken heart.

Antoine Priore

Antoine Priore’s electromagnetic therapy machine was perfected during the 1960’s and early 70’s as a team of leading French scientists demonstrated “conclusive, total remissions of terminal tumors and infectious diseases in hundreds of laboratory animals…funded by the French Government. The approach employed very complicated mixing of multiple EM signals in a rotating plasma, and modulating the mixed output upon a very strong rippling magnetic field to which the body of the test animal was exposed. Complete remission of the treated diseases was obtained. In addition, the animals’ immune systems were also restored to normal…In the mid-70’s Priore’s work was suppressed, because of hostility of the oncology community, change of the French Government, loss of further funding, and complete inability of the physicists and biological scientists to even hypothesize a mechanism for the curative results.”¹⁸ This last reason reminds one of the thesis by Thomas Kuhn, who argues that a radical phenomenon in science will be repeatedly treated as an anomaly until a new theory can explain it.¹⁹

Chris Bird gives us an interesting insight into his life:

I will tell you about one more person—still another self-taught genius, Antoine Priore, who began working in 1944-45, right after the war, to develop an electromagnetic device which cured cancer. He got the backing of some very interesting and courageous people, including the world-famous immunologist Dr. Raymond Pautrizel, of the University of Bordeaux II, who did all the animal work.

When Dr. Pautrizel arrived on the scene, because the emotional atmosphere surrounding the cancer cure was so great, he decided to take the research in another direction and began to use the machine to treat what he knew best, which was sleeping sickness in animals. Sleeping sickness was of primary concern to Dr. Pautrizel because it is a widespread affliction in tropical countries
and, perhaps because he was born and raised in Guadeloupe in the Caribbean, he had become very interested in tropical medicine. When he injected rabbits with the pathogen trypanosome, which causes sleeping sickness, the trypanosome would multiply until there were billions of them circulating in the bloodstream and the rabbits would uniformly all die within 72 hours. But, when exposed to the radiation of the Priore device, these same rabbits would live. Yet their blood was still teeming with the trypanosomes, which could be extracted from the radiated rabbits and injected into other control rabbits, which would then die.

This implies that the machine was doing something electromagnetically to the immune system of the rabbits such that they were able to fight off a lethal disease which would normally kill them in 72 hours!

Had it not been for the courage of Dr. Robert Courrier, who at that time was Perpetual Secretary of the Academy of Sciences of France, in the face of great criticism, the scientific data on 20 years of that work might never have been published. Time after time, over 20 years or more, Dr. Courrier personally introduced the papers for publication in the *Comptes Rendues* (Proceedings) of the French Academy of Sciences. There are 28 such papers. Even this could not prevent Dr. Pautrizel from nearly being fired from his post at the University of Bordeaux II, where he finally treated human patients successfully with the Priore device.

When he wrote a paper and sent it this time to the Academy of Medicine, it was refused without explanation. Pautrizel then wrote a long letter, since made public, to the governing offices of the French Academy of Medicine to find out why the paper had been refused and which people on the jury refused it, so that he could consult with them in order to better inform them of the facts. For 3 1/2 years he received no reply.

So then he decided to step outside of normal scientific channels and offered his story to a journalist who wrote an extraordinary book called *The Dossier Priore, A Second Affaire Pasteur?* Because the book has not been translated from French, and may not be (because it was written for a French audience and should really be rewritten in English) it is not accessible to English readers. But I have written a 50-page paper which is a synopsis of it.

We have discussed the cases of four intrepid researchers. Of these, three had no formal academic training—Priore, Naessens and Rife—and yet they went on to develop the most extraordinary medical tools in energy medicine that I think exist. Two of them were put to trial! One was nearly fired from his position. All this is moving and largely unknown medical history and all of it affords real opportunities for further exciting research.

Robert Becker

A pioneering medical doctor in the 1960’s, Dr. Becker is most famous for his book, *The Body Electric*, which gives an autobiographical account of his life’s experiences with bioelectromagnetics. Not only did he establish that the Chinese meridians of the body are skin pathways of decreased electrical resistance but he discovered a host of other bioelectric effects within the body as well, such as electrostimulating limb-regeneration in mammals. He also worked on electrically stimulating bone growth with Dr. Andrew Bassett, who along with Dr. Arthur Pilla, developed a very effective PEMF generator to stimulate bone fracture healing, now
approved by the FDA with an 80% success rate. Similar PEMF signals recently have been used effectively to prevent osteoporosis even in patients with an ovariectomy. 

Abraham Liboff

A modern-day physicist and inventor, Dr. Abraham Liboff is the discoverer of electric-field and geomagnetic ion cyclotron resonance, which more reliably explains the resonant interaction of static magnetic fields with endogenous AC electric fields in biological systems.23,24 A physicist with Oakland University, he has introduced significant physics principles into the field of bioelectromagnetics. His “Method and Apparatus for the Treatment of Cancer” (US Patent #5,211,622) tunes an alternating magnetic field, superimposed on a static magnetic field, to maintain a combined effect that has the proper cyclotron resonance frequency so that the neoplastic tissue containing a preselected ion can be treated to bring about a decrease in the proliferation rate of the cancer cells. It also can be combined with a chemotherapeutic agent for a synergistic effect. However, it is noted in the patent disclosure that “up to 100 days of treatment will provide beneficial results.”

Stimulated Biophoton Emission

In 1976, Bernard Ruth rediscovered evidence of a very weak but permanent photon emission from living tissue, while doing research for his doctoral dissertation.25 The

Figure 1

![Figure 1](image-url)
findings of his research team led by Fritz Albert Popp, subsequently proved experimentally that biophotons exhibit multimode coherent properties akin to laser light and not merely spontaneous chemiluminescence which is chaotic. One example is the unusually high transparency of tissue to biophoton light. It is an interesting phenomenon, which coincides with “light piping” in plant tissues, by which nature apparently ensures that several centimeters of cellular cytoplasm hardly attenuate the amplitude of biophoton intensity. Experimental data of the extinction coefficient of wet sea sand and soya cells at 550 nm from a Guilford spectrophotometer, compared to biophotons emitted by cucumber seedlings passing through the same sand and soya, reveal the lowest value (a constant 0.2/mm value for E/d) for the biophotons passing through 5 cm of soya cell cultures. A well-developed biophysical hypothesis suggests that biogenic, long-distance intercellular communication implies information transmission.

The total number of biophotons emitted by normal cells, when exposed to white light, decreases, not exponentially but with a hyperbolic relaxation of photon intensity after exposure, extending up to an hour. “Under ergodic conditions, hyperbolic decay is a sufficient condition for coherent rescattering.”

The emission of biophoton light by cancerous cells when exposed to white light, versus the slow decline in emission levels by healthy cells upon irradiation by white light, demonstrates a remarkable difference (see Figure 1). The HTC cell curve, representing malignant liver cells shows an exponential increase in activity with a linear cell density increase. The weakly malignant cells (H35 cells) show a slight increase, while the normal (Hepatocytes) display a linear decrease with increasing cell density as they store the light energy. One proposed cellular communication hypothesis might correlate the experimental rate of biophoton emission vs. density with stimulating mitosis or proliferation. Normally a cellular colony would reduce such multiplication upon receiving evidence of overcrowding. Instead, cancer cells not only have no such limits, as is well-known, but the evidence suggests a tendency, as seen in Figure 1, for positive feedback, if such a correlation exists. Growth regulation through biophoton emission normally follows a nonlinear (proportional to the square of the number of cells) inhibition, confirmed by experiment, which shows a capacity for coherent superposition of biophoton modes. It is quite possible that the Rife style of Tesla devices stimulate healthful biophotons.

**Description of High Voltage Tesla PEMF Devices**

While there are numerous other classes of BEM devices, as seen with the Priore machine, the Liboff device, and even pain fighters, this investigation centers on the High Voltage Tesla (HVT) class of BEM therapy PEMF devices. The standard Tesla coil, with a spark gap between the capacitor and high voltage transformer, sets the standard for this class of high voltage BEM devices which are of particular interest. Up until now, the lack of biophysical knowledge surrounding their operation has impeded, in this author’s opinion, their widespread acceptance into the medical profession. They are pulsed by virtue of an intermittent high voltage conduction component, by means of a relay, switch, or simply the spark gap, sometimes with square wave characteristics.

Examples of the HVT PEMF devices are the Tesla Coil, Lakhovsky MWO, the Rife Frequency Instrument, and recently, the Natural Energy Institute’s Electronic Wind Faser
(soliton@optonline.net), the Azure Therapy Device (US Patent #6,217,604), the Vibration Integration Biophotonic Energizing (VIBE) device (www.vibe-machine.com), the Tesla Photon Machine (www.altcancer.com), the Pappas Pulsed Magnetic Induction Device (MID) (US Patent #5,068,039 and #5,556,418), and the Light Beam Generator (www.LightBeamGenerator.com).

Stages and Modality of PEMF Effects

In determining the most likely biophysical reactions, this investigation begins with some bioelectromagnetic statistics. The resistivity, conductivity, dielectric constants, etc. of the human body are all known in the literature. There are many stages and possible modalities of EMF and PEMF interaction with the body. Starting from the exogenous field penetration, known interactions with cellular metabolism are examined.

Skin Depth of HVT PEMF

For example, it has been established that high frequency electromagnetic fields (EMFs) can penetrate several centimeters into tissue, bone, and muscle.\(^{32}\) Immunological effects of in vivo RF exposure often results an improvement or stimulation when local hyperthermia is induced with continuous wave, gigahertz frequencies of approximately 100 watts per square meter intensity.\(^{33}\) However, without local hyperthermia induced, the biophysics of the effects on the tissue is less obvious. At least, it can be reasonably that HVT PEMF’s also penetrate deeply into the body. The various effects of the PEMF’s inside the body are explored below.

Negative Ion Effects

It is well-known that negative ions and traces of ozone have a wide range of health benefits, including boosting the immune system and killing germs.\(^{34}\) Since high voltage Tesla PEMF devices provide an abundance of negative ions and traces of ozone, the hypothetical neuroendocrine cell-initiated reflex arc may also apply to explain neurological benefits.\(^{35}\)

Transmembrane Potential

Another important aspect of the biophysical effects from HVT PEMF’s can be found in analyzing the transmembrane potential (TMP). For example, it is known that damaged or diseased cells present an abnormally low TMP about 80% lower than healthy cells.\(^{36,37}\) This signifies a greatly reduced metabolism and, in particular, impairment of the sodium-potassium (Na-K) pump activity and ATP production.

It is proposed that cell membranes may, in fact, rectify alternating currents since structured proteins behave like solid-state rectifiers.\(^{38}\) It is reasonable therefore to conclude, based on these biophysical principles, that any endogenous HV EMF potential of sufficient strength will theoretically stimulate the TMP, normal cell metabolism, the Na-K pump, ATP production and healing. This has already found in the literature: “TMP is proportional to the activity of this pump and thus to the rate of healing.”\(^{39}\)
Adaptability of Organisms to Electromagnetic Energy

**Before EMF**  

**Electronic Excitation**  

**Polarization**  

**Field-Induced Force**  

**Heat**  

**Other Processes**

Figure 2
“Increases in the membrane potential have also been found to increase the uptake of amino acids.” Healthy cells, according to Nobel prize winner Otto Warburg, have cell TMP voltages of 70 to 90 millivolts. Due to the constant stresses of modern life and a toxic environment, cell voltage tends to drop as we age or get sick. As the voltage drops, the cell is unable to maintain a healthy environment for itself. If the electrical charge of a cell drops to 50, a person may experience chronic fatigue. If the voltage drops to 15, the cell often can be cancerous. Dr. Warburg also found in 1925 that cancer cells function best in the absence of oxygen, in effect, living on fermentation rather than respiration.

Multiple Interactions with EMF

To address some of the complex modalities of interaction with electromagnetic fields, Figure 2 offers a standard set of (1) electronic excitation to a higher energy level following the absorption of electromagnetic energy in the visible or UV spectrum, which is also capable of altering chemical bonds; (2) polarization which, if the dipoles are attached to a membrane, could alter membrane permeability; (3) forces on induced dipoles cause pearl-chain formation for fields above 10 kV/m; (4) heat effects are a “ubiquitous consequence of EMFs” but independent of the details of molecular activity; (5) other processes that have sensitivities as low as one billionth of a microwatt per square centimeter ($10^{-9}$ W/cm$^2$). Such processes include quantum mechanical and classical processes of superconductivity, Hall effect, converse piezoelectric effect, cooperative dipole interactions, and plasma oscillations. The #5 processes are “theoretically capable of serving as the underlying physical mechanism for any known EMF-induced biological effect.”

High Voltage Effects

Research has shown that simple high voltage electrostatic fields can have many effects on the human body, most of which appear to be favorable. For example, HV fields in the range of 2400 kV/m (2.4 MV/m) were found to have a beneficial effect on mice as measured by their activity, rate of liver respiration, and ability to form antibodies. In contrast, mice which were deprived of any electrostatic fields by being enclosed in a Faraday cage showed opposite results. (It is noted that the outdoor, ambient electrostatic field caused by the ionosphere to earth potential is approximately 100 V/m and rises during thunderstorms.) Not only does such research imply a correlation to immunological ability but it also implies another important aspect of BEMs: The endogenous electric field strength, within a few centimeters of bone or tissue, will usually be in the range of only 10 mV/m for an exogenous field of 1 MV/m at 10 Hz or less. (The earth-ionosphere Schumann cavity for example, resonates fundamentally around 10 Hz.) However, the endogenous voltage relationship is a decreasing logarithmic with frequency, so that an exogenous MHz range signal need only be 100 V/m to create the same 10 mV/m internally. Higher frequency EMFs thus have correspondingly higher endogenous fields. As an application example, it has been found that a temporal peak electric field magnitude of approximately 150 mV/m averaged within the medial cartilage of the knee, when stimulated by an osteoarthritis therapy, 0.12 mT coil with 260 microsecond pulses.
Pulsed electric or magnetic fields are also found to be another recourse, if it is understood that higher endogenous field strengths are desirable. Another example is a 100 kV/m electric field which has been shown to improve the synthesis of macromolecules, such as DNA or collagen (which forms connective tissue). However, if the field is interrupted at least once per second (pulse rate of 1 Hz), DNA synthesis goes up 20% higher than the previous measurement and collagen synthesis by 100%. A dependence on the field strength is also found. It has been proposed that only one PEMF device operates close to the minimum electroporation gradient of 1 kV/cm (100 kV/m). That is the Pappas Pulsed MID which has reported success in relieving 89% of acute or chronic pelvic pain and explains that, “Electroporation is a universal, non-thermal, bioelectrochemical phenomenon relating to the rate of two-way transmigration of chemical ions through the cell membrane, defining the cell’s metabolic rate and hence energy level.”

In perspective, it may be noted that HVT PEMFs such as the Azure device and those like it may not achieve the high endogenous fields for creating electroporation but most likely stimulate membrane permeation through HF effects noted below, confirming the abundance of healing anecdotal reports. Dr. Robert Adair notes that without utilizing pulsed signals, continuous (AC) RF devices need to exceed 10 mW/cm² in order to exceed the ubiquitous endogenous noise in biological systems.

Concerns about endogenous HV safety issues have also been addressed in the literature. Recent experiments confirm that a two-minute exposure to 100 kV/m peak electric field, and a pulse duration of 1 ns “does not have an immediate detrimental effect on the cardiovascular system…” Also confirmed is that “nonthermal biohazards seem unlikely in the ultra-high frequency range” with the chief physical loss mechanism being ionic conduction and dielectric relaxation.

**High Frequency Effects**

When studying high voltage, especially with Tesla coils, it is also important to examine the BEM high frequency effects that are also well-known. The average specific absorption rate (SAR) for a human body for example, is measured in watts/kilogram (W/kg) and has an increasing logarithmic dependence with frequency up until 1 gigahertz (1 GHz) where it levels out at about 10 W/kg. The power absorption density for muscle
per incident milliwatts per cm$^2$ also levels out around 1 GHz.\textsuperscript{51} This is valuable information for analyzing HVT PEMF devices since they operate in a broadband of frequencies, often with two resonant peaks in the kilohertz or megahertz range but still generating measurable energy extending well into the GHz range.\textsuperscript{52} EMFs in the GHz range (1.8 GHz) have been shown to increase the permeability to sucrose of the blood-brain barrier in vitro.\textsuperscript{53}

Also, as noted previously, higher frequency EMFs have correspondingly higher endogenous fields. This has been dramatically confirmed with experiments on human eosinophils in vitro. When 3 – 5 pulses with electric field intensities of up to 5.3 MV/m and 60 ns (nanosecond) duration were applied to the human eosinophils, intracellular granules were modified without permanent disruption of the plasma membrane. In spite of the ultrashort electrical power levels applied to the cells, thermal effects could be neglected because of the ultrashort pulse duration. “The intracellular effects extends conventional electroporation to cellular substructures and opens the potential for new applications in apoptosis induction, gene delivery to the nucleus, or altered cell functions, depending on the electrical pulse conditions.”\textsuperscript{54} It is noted that pulses with nanosecond periods will correspond to frequencies in the gigahertz range by a simple inverse relationship.

Demodulation of amplitude modulated radio frequency (RF) energy has been proposed as a mechanism for the biological responses to these fields. An experiment is also proposed that tests whether the electric and magnetic structures of biological cells exhibit the nonlinear responses necessary for demodulation:

A high Q cavity and very low noise amplification can be used to detect ultraweak nonlinear responses that appear as a second harmonic of a RF field incident on the sample. Nonlinear fields scattered from metabolically active biological cells grown in monolayer or suspended in medium can be distinguished from nonlinearities of the apparatus. Estimates for the theoretical signal sensitivity and analysis of system noise indicate the possibility of detecting a microwave signal at 1.8 GHz (2nd harmonic of 900 MHz) as weak as one microwave photon per cell per second. The practical limit, set by degradation of the cavity Q, is extremely low compared to the much brighter thermal background, which has its peak in the infrared at a wavelength of about 17 m and radiates $10^{10}$ infrared photons per second per cell in the narrow frequency band within 0.5\% of the peak. The system can be calibrated by introduction of known quantities of nonlinear material, e.g., a Schottky diode. For an input power of 160 W at 900 MHz incident on such biological material, the apparatus is estimated to produce a robust output signal of 0.10 mV at 1.8 GHz if detected with a spectrum analyzer and a 30-dB gain low noise amplifier. The experimental threshold for detection of nonlinear interaction phenomena is $10^{10}$ below the signal produced by a Schottky diode, giving an unprecedented sensitivity to the measurement of nonlinear energy conversion processes in living tissue.\textsuperscript{55}

Electron Transport and Free Radicals

Quite possibly the most comprehensive and significant for general disease states including cancer, relates to the science of free radicals in the human body. Free radicals contain an odd number of electrons. An example is a methyl radical or a chlorine radical.
It is known that homolytically cleaved covalent bonds break in such a way that each fragment retains one electron of the bond. Oxygen or chlorine are such examples. (Chlorine gas is readily available in small amounts within the home when anyone turns on a water faucet in a metropolitan area throughout the US, without using a charcoal filtration system.) Since molecular chlorine has a rather low bond-dissociation energy (58 kcal/mole) chlorine atom radicals may be produced by light of relatively long wavelength or heating to moderate temperatures. Once chlorine atom radicals are present in a small amount, a chain reaction commences. They can continuously react with another molecule to produce another free radical, going through 10,000 cycles before termination.

Antioxidants are the most common types of “terminators” for the chain reaction caused by free radicals, since they offer an extra free electron, which the radical seeks to complete an outer shell. Many types of free radicals exist within our bodies and have been connected with the aging process, most apparent externally by the appearance of skin wrinkling. Antioxidants, donors of free electrons, are used externally to reduce wrinkles on the skin and internally to slow the aging process and halt many disease processes. Coenzyme Q-10 can function, for example, as a co-enzyme over and over again as an electron transfer agent or antioxidant.

Looking to a simple analysis of the electron transport chain found in the Krebs cycle, it produces ATP through chemiosmotic phosphorylation. It can be proposed that as the high energy electrons are transferred to ubiquinone (Q) and cytochrome c molecules, which are the electron carriers within the membrane, free radicals may interfere with the process before the electrons reach the mitochondrion, thus decreasing energy metabolism. In fact, Dr. William Koch found that “polymerizing unsaturated free radicals of low molecular weight stimulated cancer development decidedly...The free radical formed thus at the other pole...continues the polymerization process that supplies the energy for uncontrolled mitosis.”

It is proposed hypothetically that HVT PEMF devices offer abundant free electrons to the human body, in addition to plentiful negative ions, since they possess a unique static field modulated with a multimode pulsed electric field. Such a flood of free electrons, penetrating through permeable membranes throughout the tissues, muscles and perhaps the bones, not only halt the chain reactions in process, but also most likely force the fermentation production of ATP in the Krebs cycle back into a respiration cycle, in the presence of neoplastic, carcinogenic cells. Any cancer cells thus affected cannot tolerate the respiration cycle, as is well known, with its oxygen abundance and instead, immediately expire. The discharging of toxic residue then may become an important task, requiring only short HVT PEMF exposures and detoxifying interludes.

Light Effects

It has been found that light can offer a photodynamic effect on the body and entire books have been written about the specific therapeutic effects of various frequencies of visible light. Dr. John Ott conducted experiments showing that mice living under pink fluorescent light were more likely to develop cancer and reproductive problems. Dr. William Douglass states, “Photonic medicine should soon be used for diagnosis as well as therapy.” Interestingly enough, regarding the HVT PEMF devices which also add
Rife gas tubes to the antenna, (see Azure patent #32 in Figure 3) it has been shown that PEMF and photooxidation together yield “lethal effects on cancer cells.”

**Conclusion**

In conclusion, the PEMF devices that are known to utilize a Tesla coil, for the HF and HV PEMF, include the Azure patent assigned to Healing Machines, Inc., the VIBE Machine, the Tesla Photon Machine, the Light Beam Generator, the Lakhovsky multiwave oscillator (MWO), and Natural Healing Institute’s Electronic Wind Faser. Several of these also add biophoton-stimulating high voltage gas tubes which appear to have an additional effect on the body. See the book by T. Valone for more information.

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Detection of thirteen resonances of radio waves from particularly intense lightning discharges

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Received 18 March 2005; revised 2 May 2005; accepted 1 June 2005; published 6 July 2005.

[1] Thirteen resonances of radio waves from particularly intense lightning discharges in the Earth’s atmosphere are detected in the frequency range from 5–90 Hz. The inferred frequency dependent relative wave propagation velocities are in excellent agreement with theoretical predictions. The full sequence of the resonance frequencies may be used to monitor the global ionospheric D-layer height variability resulting from space weather phenomena. Citation: Füllekrug, M. (2005), Detection of thirteen resonances of radio waves from particularly intense lightning discharges, Geophys. Res. Lett., 32, L13809, doi:10.1029/2005GL023028.

1. Background

[2] Particularly intense lightning discharges in the troposphere transmit radio waves at extremely-low frequencies [Sentman, 1995], which propagate with little attenuation within the Earth’s atmosphere [Chapman and Jones, 1964] and exhibit constructive interference, denoted Earth-ionospheric cavity (or Schumann) resonance. This electromagnetic resonance phenomenon in a thin spherical shell geometry was predicted theoretically [Schumann, 1952] prior to experimental confirmation [Balser and Wagner, 1960]. These first observations reported five resonance frequencies from 7.8 to 32.5 Hz based on the spectral analysis of 2 hour long recordings of naturally occurring radio noise. The determined center frequencies of the resonances were supported by numerical model computations [Madden and Thompson, 1965], which were undertaken to infer a mean global conductivity profile of the lower ionosphere. A similar investigation used radio waves from intense lightning discharges with a comparison to numerical model computations and reported the detection of six resonances from 7–38 Hz [Jones and Kemp, 1970; Ogawa et al., 1979]. Eight distinct resonances were detected in the frequency range from 7–52 Hz by use of 24 hour long recordings of radio noise [Sentman, 1987], supported by analytical modeling based on Maxwell’s equations [Sentman, 1990, 1996]. These results were experimentally confirmed by use of radio noise recordings during an effective time interval of 2.6 days [Füllekrug and Fraser-Smith, 1996]. It may be concluded that further averaging of radio noise recordings can not detect additional resonances, since the latter measurements were undertaken at an extremely quiet site in an electromagnetic environmental protection area [Fraser-Smith et al., 1992]. On the other hand, recent theoretical model calculations indicated the possible existence of up to eleven resonances [Nickolaenko and Hayakawa, 1998]. If confirmed, this finding would explain in a natural way the conundrum that only the radio noise in the frequency range from 5–100 Hz (and not from 5–50 Hz, as eight globally observable resonances do imply) exhibits a diurnal variation with universal time, which is similar to the diurnal variation of the atmospheric electric field (Carnegie curve), since both variations are thought to result from global lightning activity [Holzer and Deal, 1956; Füllekrug et al., 1999]. It may therefore be speculated that resonances do indeed exist in the frequency range from 52–100 Hz, but that they remain undetected as a result of the limited bandwidth of the measurement instruments and/or the statistical analysis methods used. This letter reports the detection of five additional resonances in the frequency range 55–90 Hz by use of broadband recordings of radio waves from particularly intense lightning discharges.

2. Observations and Modeling

[3] The radio waves are recorded with induction coil magnetometers in Silberborn, Germany, during April 1998. The location was chosen for its particularly quiet electromagnetic environment with little interference from power line radiation at 50 Hz and higher harmonic frequencies. The original recordings are corrected for the instrumental response and the remaining narrow band interference from power line harmonic radiation is removed during the digital pre-processing of the data. One second long time intervals of the broadband (0.5–200 Hz) waveforms from 52510 globally triangulated particularly intense lightning discharges are extracted [Füllekrug and Constable, 2000], transformed to the frequency domain and averaged into one spectrum for all source receiver distances from 2–18 Mm [Füllekrug, 2000]. Seven resonances are immediately apparent in the resulting spectrum (Figure 1, left panel). Six additional resonances are detected upon enlargement of the graphical display (Figure 1, right panel). The magnetic field amplitudes at the resonance frequencies decrease with increasing frequency such that the resonances at higher frequencies are more difficult to detect. For comparison of the observational results with theoretical model calculations, the short pulse approximation of the normal mode expansion with frequency dependent ionospheric heights

\[
B_1(\omega, \theta) = \frac{Q_l}{4\pi a^2 h_1(\omega) \omega} \sum_{n=0}^{2n+1} \left( \frac{2n+1}{(\omega - \omega_n)(\omega + \omega_n)} \right) P_l^1(\cos \theta) \tag{1}
\]
is used [Sentman, 1996; Füllekrug, 2000]. In this approach, the theoretical spectral magnetic field amplitude $B_t(\omega, \vartheta)$ is related to the intensity of the lightning discharge, the geometric spreading of the radio wave and the ionospheric transfer function. The intensity of the lightning discharge is characterised by the charge moment $Q_l$, which describes the amount of charge $Q$ lowered from cloud to ground within a vertical lightning channel of length $l$. The geometric spreading of the radio wave is described with the associated Legendre polynomials $P_n^m(\cos \vartheta)$ of degree $n$ and order $m = 1$ at an angular distance $\vartheta$ from the lightning discharge on a spheroidal Earth with radius $a$. The ionospheric transfer function is characterised by the frequency dependent conduction boundary $h_1(\omega) \approx 50$ km, where the displacement and conduction current become equal, and the complex modal frequency

$$\omega_n = \sqrt{n(n+1)} \frac{c}{a} \sqrt{\frac{h_1(\omega)}{h_2(\omega)}} \left[ 1 - i \frac{\pi}{4} \left( \frac{s_1}{h_1(\omega)} + \frac{s_2}{h_2(\omega)} \right) \right]$$

[Greifinger and Greifinger, 1978; Sentman, 1990; Füllekrug, 2000], where $h_2(\omega) \approx 100$ km is the ionospheric height where the radio waves are reflected and $s_1 \approx s_2 \approx 2.5$ km are scale heights, which determine the exponential increase of the ionospheric conductivity in the atmosphere. The theoretical magnetic field spectrum is shown for comparison with the observed spectrum in Figure 1. The

Figure 1. Thirteen resonances are detected in the observed magnetic field spectrum of radio waves from particularly intense lightning discharges (solid lines). The observations are supported by the theoretical magnetic field spectrum calculated with the short pulse approximation of the normal mode expansion with frequency dependent ionospheric heights (dashed lines). A simple scaling law can be used to approximate the decrease of the spectral amplitudes with frequency of the theoretical magnetic field spectrum (right panel, inset, dashed dotted line).

Figure 2. The transfer function between the observed and the approximated magnetic field spectrum (*) and the transfer function between the theoretical and the approximated magnetic field spectrum (x) reveal the full sequence of thirteen resonance frequencies from 5–90 Hz. The center frequencies of the resonances (o) are determined from the relative maxima of the harmonically interpolated transfer functions (solid and dashed lines) with a frequency resolution of 10 mHz.
3. Conclusions

Ten resonances of radio waves from particularly intense lightning discharges are detected in the frequency range 5–90 Hz. The observed resonance frequencies are used to determine relative wave propagation velocities in excellent agreement with theoretical predictions. The relative wave propagation velocities are subsequently used to infer a mean global ionospheric conductivity profile. The entire analysis is based on one second long observations of radio waves from particularly intense lightning discharges, which occur about once per minute [Fülllekrg and Constable, 2000; Sato and Fukunishi, 2003]. It seems therefore plausible that a network of measurement instruments around the globe could simultaneously detect the radio waves from individual lightning discharges and determine the resonance frequencies in real time to infer a mean global ionospheric conductivity profile, which may be determined with a time resolution of one minute to monitor the global ionospheric D-layer height variability resulting from space weather phenomena.

Acknowledgment. I wish to thank Kristian Schlegel for drawing my attention to the challenging science of space weather and Earle Williams for discussions on the extent of the resonant radio wavespectrum at extremely-low frequencies.

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Schumann Resonances in Lightning Research

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Abstract
Schumann resonances (SR) are global electromagnetic resonances excited primarily by lightning discharges. This review is aimed at the reader generally unfamiliar with Schumann resonances. Our goal is to give some historical context to SR research, and to show the extensive use of Schumann resonances in a variety of lightning-related studies in recent years, ranging from estimates of the spatial and temporal variations in global lightning activity, connections to global climate change, transient luminous events and extraterrestrial lightning. We present both theoretical and experimental results of the global resonance phenomenon. It is our hope that this review will increase the interest in Schumann resonances among lightning researchers previously unfamiliar with Schumann resonance studies. Keywords: Schumann resonance, lightning, ELF, climate, transient luminous event, planetary lightning.

Index Terms
Schumann Resonance, ELF, global lightning

1 INTRODUCTION
Schumann resonances (SR) are global electromagnetic resonances excited primarily by lightning discharges in the cavity between the Earth surface and the ionosphere. SR are observed in the power spectra of the natural electromagnetic background noise, as separate peaks at extremely low frequencies (ELF) around 8, 14, 20, 26 and 32 Hz (Figure 1).

The first suggestion that an ionosphere existed, capable of trapping electromagnetic waves, was made by Heaviside and Kannelly in 1902. It took another twenty years before Appleton, in 1924, was able to prove experimentally the existence of the ionosphere. However, even prior to this the first documented observations of global electromagnetic resonances were made by Nikola Tesla and formed the basis for his scheme for wireless communication [1]. Although some of the most important mathematical tools for dealing with spherical waveguides were developed by Watson [2], it was Winfried Otto Schumann who first studied the theoretical aspects of the global resonances of the earth-ionosphere waveguide system, known today as the Schumann resonances. Schumann, together with Köning, attempted to measure the resonant frequencies [3-6]. However, it was not until measurements made by Balser and Wagner [7-11] that adequate analysis techniques were available to extract the resonance information from the background noise.

Since then there has been an increasing interest in SR in a wide variety of fields. From the very beginning of SR studies, they were used to track global lightning activity [9, 12-15]. As a result of the connection between lightning activity and the Earth's climate, it has been suggested that SR may be used to monitor global temperature variations [16] and variations of upper water vapor [17, 18]. It was suggested that extraterrestrial lightning may also be detected and studied using SR [19-21]. SR has been used for research and monitoring of the lower ionosphere on Earth and suggested for exploration of lower ionosphere parameters on celestial bodies [19, 22]. One of the most interesting applications of SR research is the tracking of large-scale ionospheric perturbations. SR can help track geomagnetic disturbances, such as solar proton events, solar flares and γ-ray bursts [23-32]. Nuclear explosions have also been known to leave their signature in SR records [11, 33, 34]. More recently, Schumann resonances are used for monitoring transient luminous events – sprites and elves [35-39]. A new field of interest using SR is related to short-term earthquake prediction [40-42]. Schumann resonances have gone beyond the boundaries of physics, invading medicine [43], while raising interest in artists and musicians, and conquering such exotic fields as psychobiology and yoga. In this review we will
concentrate only on Schumann resonance studies associated with lightning research.

2 THEORETICAL BACKGROUND

Lightning discharges are considered as the primary natural source of SR. Lightning channels behave like a huge antenna which radiates electromagnetic energy as signals of impulsive nature at frequencies below about 100 kHz [44]. Lightning signals below 100 Hz are very weak, but the earth-ionosphere waveguide behaves like a resonator at ELF frequencies and amplifies the spectral signals from lightning at the resonance frequencies [44].

If the terrestrial waveguide was an ideal one, the resonant frequencies $f_n$ would have been determined by the earth’s radius $a$ and the speed of light $c$ – (1) [3]. However, the Earth-ionosphere waveguide is not a perfect electromagnetic cavity. Losses due to finite ionosphere conductivity make the system resonate at lower frequencies than would be expected in an ideal case, and the observed peaks are wide. In addition there are a number of horizontal asymmetries – day-night transition, latitudinal changes in the Earth magnetic field, sudden ionospheric disturbances, polar cap absorption, etc. that complicate the SR power spectra.

$$f_n = \frac{c}{2\pi a} \sqrt{n(n+1)}$$ (1)

The problem of wave propagation in the Earth-ionosphere cavity is most naturally formulated in spherical coordinates $(r, \theta, \phi)$. The excitation source is represented by a vertical dipole with a current moment $(Ids)$ located between two concentric spherical shells at $\theta=0$. Radius of the inner shell – the Earth, is denoted by $r=a$, and the radius of the outer shell – the ionosphere – by $r=a+h$, assuming sharp and frequency independent upper boundary. Both the observer and the source are assumed to be located on the Earth surface. Maxwell equations are then solved assuming time dependence of $e^{i\omega t}$ and requiring continuity on the boundaries (ground-cavity transition at $r=a$, and cavity-ionosphere transition at $r=a+h$). The electric and magnetic components are then [44]:

$$E_r = i \frac{Ids}{8\pi a^2 \varepsilon_0} \frac{\nu(\nu+1) P_\nu^0(-\cos \theta)}{h \sin \nu \pi}$$ (2)

$$H_\phi = \frac{-Ids}{4a} \frac{1}{h} \frac{P_\nu^1(-\cos \theta)}{\sin \nu \pi}$$

The resulting fields are shown in Figure 2 for the first three SR modes.

In (2) $\varepsilon_0$ is a free space permittivity and $P_\nu^l$ are the associated Legendre functions. Complex parameter $\nu$ is calculated in terms of complex sine of the wave incidence angle $S$ via [45]:

$$S^2 = \nu(\nu+1)/(k_0a)^2$$ (3)
where $\kappa_0$ is the free space wave number. The dimensionless quality factor $Q$ of the resonant cavity may be determined as a ratio between the stored energy and the energy loss per cycle. Considering only the electrically stored energy [45]:

$$ Q = \frac{\text{Re} \cdot \mathcal{S}}{2 \cdot \text{Im} \cdot \mathcal{S}} $$

(4)

On Earth, the resonance is characterized by a quality factor $Q$ ranging from 4 to 6 [46].

More realistic models are far more complex. Methods of introducing more complicated ionosphere structure include two-layer [48] and multi-layer models [49-52], and the more realistic two-exponential [53], “knee” [54], and “multi-knee” [21] profiles.

3 SR MEASUREMENTS

The electromagnetic sensors used to measure Schumann resonances consist of two horizontal antennas for receiving the magnetic field in the north-south direction ($H_{NS}$) and the east-west direction ($H_{EW}$) and one vertical antenna for observing the vertical electric field, $E_Z$ (Figure 3). Since Schumann resonance frequencies are extremely low, practical antennas would have to be hundreds of kilometers long. In addition, the SR electric field is of the order of mV/m, which is much smaller then the static electric field in the atmosphere which ranges from 100V/m in the fair weather to kV/m on a stormy day. Furthermore, the SR magnetic field is in the pT range – orders of magnitude smaller then the Earth’s magnetic field. Therefore, special receivers and antennas are required to measure SR. The electric component is commonly measured with a ball antenna, suggested by [55], connected to a high-impedance amplifier. The magnetic field is measured with magnetic induction coils consisting of tens of thousands of turns around material with very high magnetic permeability.

The sampling frequency can vary from several tens of Hz to a few hundreds of Hz in order to cover the SR band without aliasing. It is advisable to save all raw data for later post-processing, although some groups use real-time analysis and save only the spectral parameters of the SR (peak frequency, peak amplitude, and Q-factor) [56], together with short time segments of ELF transients. In the time domain, the electric and magnetic signals consist of a background signal, which is a superposition of individual pulses arriving from about 50 random lightning flashes per second occurring all over the world. Superimposed upon the background noise are intense transients from individual powerful lightning discharges, with amplitudes often ten times higher than that of the background noise [57]. After processing the time series' by using the Fast Fourier Transform (FFT) algorithm, SR modes can usually be observed in the frequency domain at 8, 14, 20, 26… Hz.

Man-made noise produces various interferences in the ELF ranging from radiation from power supply lines to traffic and pedestrians [46], forcing to locate SR measuring stations in isolated rural areas, away from industrial activity. At the site the electromagnetic field sensors should be located away from power supply lines. Complete battery supply is preferable, but is expensive and limits long-term monitoring. Open spaces with uniform underlying geology and well conducting soil should be chosen for the site [46]. The field sensors are exposed to external static fields – fair weather field of ~100 V/m and the geomagnetic field of ~0.5 Gauss, and therefore the slightest vibration of an antenna will result in a huge signals induced at the input of the receiver. Hence the horizontal magnetic antennas are buried in the ground to avoid the signals induced by ground vibrations or wind. Ideally, electric and magnetic channels should be identical, be calibrated periodically, sampled using a 16 bit A/D (analog-to-digital) converter, a notch filter for the industrial 50 Hz interference, and be equipped by a GPS clock for time stamps.

The duration of data collection of up to 10 minutes is needed to obtain stable estimates of the SR spectrum. Nickolaenko and Hayakawa [46] suggest that this may explain the unsuccessful early experiments by Schumann and König [6] focused on the detection of the global resonances: the natural signal is actually
random "noise", and the resonance peaks become visible only after relatively long integration time. A 10 minutes interval was used in the first successful experiment by Balser and Wagner [7].

4 SR BACKGROUND OBSERVATIONS OF GLOBAL LIGHTNING ACTIVITY

At any given time there are about 2000 thunderstorms around the globe [13, 15, 16, 55, 58, 59]. Producing ~50 lightning events per second [60], these thunderstorms create the background SR signal.

Determining the spatial lightning distribution from the background SR records is a complex problem: in order to properly estimate the lightning intensity from SR records it is necessary to account for distance to sources. The common approach to this problem is based on the preliminary assumption on the spatial lightning distribution. The most widely used are the models of the three thunderstorm centers – continental and island Southeast Asia, Africa and South America [15, 61-65], and a single thunderstorm center traveling around the globe [46, 66, 67]. An alternative approach is placing the receiver at the North or South Pole, which remain approximately equidistant from the main thunderstorm centers during the day [68]. A distinct method, not requiring preliminary assumptions on the lightning distribution [69] is based on the decomposition of the average background SR spectra, utilizing ratios between the average electric and magnetic spectra and between their linear combinations.

The best documented and the most debated features of the Schumann resonance phenomenon are the diurnal variations of the background SR power spectrum. Some of the earliest studies were made by [9, 12, 70, 71]. The first investigators realized that SR field power variations were related to global thunderstorm activity [9, 12, 70, 72]. Thus SR measurements became a convenient tool for studying global lightning activity [16, 56, 61, 73-77]. Figure 4 shows the 4-year (1999-2002) mean diurnal and seasonal variations of the SR power for the first mode – individual electromagnetic components of the SR field. From [56].

In the early literature the observed diurnal variations were explained by the variations in the source-receiver geometry [9] and it was concluded that no particular systematic variations of the ionosphere are needed to explain these variations [73]. Subsequent theoretical studies supported the early estimations of the negligible influence of the ionosphere day-night asymmetry (difference between day-side and night-side ionosphere conductivity) on the observed variations in SR field intensities [46, 66, 78-80]. The interest in the influence of the day-night asymmetry of the ionosphere conductivity on SR field power arose with a new strength in the 1990s, after publication of a work by [59]. A technique was developed in [59] to separate the global and the local contributions to the observed field power variations using records obtained simultaneously at two stations. The local contribution was interpreted by [59] as ionosphere height variation. Their work convinced many scientists in the importance of the ionospheric day-night asymmetry and inspired numerous experimental studies. However recently it
was shown that results obtained by [59] can be simulated with a uniform model (without taking into account ionosphere day-night variation) and therefore cannot be interpreted in terms of ionosphere height variation [81].

5 SR TRANSIENT MEASUREMENTS OF GLOBAL LIGHTNING ACTIVITY

One of the most interesting problems in SR studies is determining the lightning source characteristics (the “inverse problem”). Temporally resolving each individual flash in the background SR signal is impossible. However there are intense ELF transient events, also named “Q bursts”, which appear as prominent excursions above the SR background signal

Figure 5 shows diurnal and seasonal amplitude variations in the electric field of the first three SR modes for Nagycenk, Hungary station (1994-2001) – the left panels, and for Mitzpe-Ramon station (1999-2002 average) – the right panels. The data recorded at both stations demonstrates significant diurnal and seasonal variations of SR fields. When plotted in this way, a characteristic lens-shape pattern is revealed. This lens-shape strongly resembles the shape of the terminator (the day-night transition) and hence is termed the “terminator effect”. Such similarity seems to support the suggestion of a significant influence of the day-night ionosphere asymmetry on SR [59, 83]. However, such variations may be as well explained by the migration of thunderstorms [46, 82].

Figure 6. Q-bursts are triggered by intense lightning strikes, associated with a large charge transfer and often high peak current [35, 55]. Amplitudes of Q-bursts can exceed the SR background level by a factor of 10 and they appear with intervals from ~10sec to a few minutes [69]. This allows us to consider the Q-bursts as isolated events and to determine the source lightning locations [66, 84-90].

The lightning location problem can be solved with either multi-station or single-station techniques. The multi-station techniques are the more accurate, but require more complicated and expensive facilities, involving a network of direction finders or time-of-arrival meters [91]. Single-station systems usually combine a direction finder with a source-receiver distance estimation technique. The transients can be geolocated with source-observer distance (SOD) or source-bearing techniques, based on the relationship between the electric and the magnetic field components [35, 37, 84, 87, 89, 92, 93]. Geolocation of source lightning can be identified with an accuracy of ~1 Mm from single-station measurements.

Source location techniques can be confirmed using general location of flashes above continental regions [84, 88], the proximity of cold cloud tops in visible and infra-red (IR) satellite images [94], global lightning measurements from space by the Optical Transient Detector (OTD) and the Lightning Imaging Sensor
SR IN TRANSIENT LUMINOUS EVENTS

RESEARCH

It is now believed that many of the SR transients are related to newly discovered transient luminous events (TLEs), spectacular optical flashes in the upper atmosphere above active thunderstorms. The existence of TLEs was theoretically predicted by [95], and many pilots have reported about this phenomenon. But the official discovery came with the first image captured above a thundercloud by [96]. In the last 15 years there has been an extensive hunt for TLEs using photography from ground stations, aircrafts and space shuttles, leading to TLE documentation in different geographical locations all over the world [97-108].

TLEs can be classified into two main classes: sprites and elves [109], although there are also blue jets, halos and trolls. Both elves and sprites are short-lived luminous events associated with mesoscale convective systems. ELVE is an acronym for “Emissions of Light and Very low frequency perturbations from Electromagnetic pulse sources”. They are dim donut-shaped glow of ~200km radius, lasting typically ~1ms occurring at altitudes of ~90-100 km. SPRITES stands for “Stratospheric/mesospheric Perturbations Resulting from Intense Thunderstorm Electrification”. Sprites are reddish-orange due to collisions of accelerated electrons with nitrogen molecules [110]. They usually occur in clutters and have forms from jelly fish to carrots, to columns. Sprites stretch from the altitude range of 40–90km with horizontal extent of tens of km and typical lifetimes of tens of ms.

The physical mechanisms responsible for sprites and elves initiation are independent of the polarity of the lightning flash [110-115]; however the vast majority of sprites and elves are initiated by positive cloud-to-ground (CG) flashes [36, 116]. These powerful positive flashes emit strong electromagnetic energy in the ELF range, indicative of continuing currents lasting over time scales of at least a few ms [116], and thus can be detected in the SR band. [36] suggested that sprites, the most common TLE, are produced by positive CG occurring in the stratiform region of a thunderstorm system, and are accompanied by large-amplitude transient pulses ("Q-burst") in the SR band. Recent observations [35-38, 90, 117] reveal that occurrences of sprites and transient SR are highly correlated.

SR records can be used to estimate the magnitude of the charge removed from cloud bottom to ground [118, 119], which appears to be one of the crucial parameters in determining which lightning discharge can produce sprites. A method of charge moment estimation of sprite-inducing CG discharges from SR data was developed by [35], who showed that the charge moments of sprite inducing CG discharges range from 200 to 2000Ckm. [120] suggested a sprite initiation probability as a function of charge moments of positive CG discharges, and hence the charge moment estimation derived from SR data can possibly enable us to estimate the global occurrence rate of sprites.

Recently, it was suggested that sprites can chemically change the concentration of NOx and HOx in the mesosphere and lower thermosphere [121]. These chemical products may lead to an impact on the global cooling or heating in the middle atmosphere, therefore it is particularly important to determine global occurrence locations and rates of sprites. Since sprites are a rather rare, occurring at rate of only a few per
minute (while regular lightning occurs at a rate of 50-100 flashes per second around the globe) SR appears to be one of the most convenient and low-cost tools for continuous TLE monitoring.

7 USING SR AS A CLIMATE RESEARCH TOOL

The warming of the Earth has been the subject of intense debate and concern for many scientists for at least the past decade. One of the important aspects in understanding global climate change is the development of tools and techniques that would allow continuous and long-term monitoring of processes affecting the global climate. Schumann resonances are one of the very few tools that can provide such global information reliably and cheaply.

It was suggested by [16] that global temperature may be monitored via the SR. The link between Schumann resonance and temperature is lightning flash rate, which increases nonlinearly with temperature [16, 122]. The nonlinearity of the lightning-to-temperature relation provides a natural amplifier of the subtle (several tenths of 1°C [123, 124]) temperature changes and makes Schumann resonance a sensitive “thermometer”. Moreover, the ice particles that are believed to participate in the electrification processes which result in a lightning discharge [125] have an important role in the radiative feedback effects that influence the atmosphere temperature. Schumann resonances may therefore help us to understand these feedback effects.

[16] compared a 5.5-year monthly mean time series of the first mode SR magnetic field data recorded at Kingston, Rhode Island (71W, 41N) with the monthly mean fluctuations in surface (dry-bulb) temperature for the entire tropics. It was shown that SR amplitude quite closely follows the temperature variations. Warmer periods were found to be associated with enhanced magnetic field amplitude, i.e. increase in global lightning activity, and colder periods – with suppressed amplitude, i.e. global decrease in lightning activity. Additional analysis using other SR data sets also show strong positive correlations between surface temperatures and SR power on seasonal and daily timescales [18]. Figure 7 presents an example of daily observations of 10Hz magnetic field recorded at Arrival Heights, Antarctica and MSU satellite temperature, showing clear correlation between the two parameters.

![Figure 7: 10Hz magnetic field records (Arrival Heights, Antarctica) and MSU satellite temperature data.](image)

Monitoring and predicting global climate change requires major advances in understanding and modeling of factors that determine atmospheric concentrations of greenhouse gases and the feedbacks that determine the sensitivity of the climate system to a given increase in those gases. Continental deep-convective thunderstorms produce most of the lightning discharges on Earth. In addition, they transport large amounts of water vapor into the upper troposphere, dominating the variations of global UTWV. Tropospheric water vapor is a key element of the Earth’s climate, which has direct effects as a greenhouse gas, as well as indirect effect through interaction with clouds, aerosols and tropospheric chemistry. Upper tropospheric water vapor (UTWV) has a much greater impact on the greenhouse effect than water vapor in the lower atmosphere [126], but whether this impact is a positive, or a negative feedback is still uncertain [127-131]. The main challenge in addressing this question is the difficulty in monitoring UTWV globally over long timescales. [17, 18] suggest that changes in the UTWV can be derived from records of SR. Figure 8 shows an example of the connection between daily SR amplitudes and upper tropospheric water vapor.

![Figure 8: Daily SR 8Hz magnetic field records and upper tropospheric water vapor.](image)
The above results show that two of the most important parameters of global climate change – surface temperature and UTWV, can be monitored with SR, utilizing its relation to worldwide thunderstorm activity. One of the great advantages of this method is availability of long-term calibrated data which can provide past and future records of global climate variations on Earth.

8 SR IN EXTRATERRESTRIAL LIGHTNING RESEARCH

Existence of Schumann resonances depends generally on two factors – presence of a substantial ionosphere with electric conductivity increasing with height from low values near the surface (or a high-conductivity layer, in case of gaseous planets) to form an ELF waveguide, and a source of excitation of electromagnetic waves in the ELF range. In Solar System there are number of candidates for SR detection: Venus, Mars, Jupiter, Saturn and its moon Titan.

The speculations that lightning occurs on Venus first arose about 30 years ago. The strongest evidence for lightning on Venus comes from the impulsive electromagnetic waves seen by the Venera 11 and 12 landers [132-135] and the Pioneer Venus Orbiter [136, 137]. On Mars lightning activity has not been detected, but charge separation and lightning strokes are considered possible in the Martian dust storms [138-141]. Jupiter is the only planet where lightning activity is well established. Existence of lightning on this planet was predicted by [142] and it is supported by data from Galileo, Voyagers 1 and 2, Pioneers 10 and 11 and Cassini [143, 144]. Although Saturn is similar enough to Jupiter to expect intensive lightning activity, the three visiting spacecrafts – Pioneer 11 in 1979, Voyager 1 in 1980 and Voyager 2 in 1981, failed to provide convincing evidence of lightning activity [144]. Recently a strong storm was monitored on Saturn by Cassini spacecraft. The storm was a possible source of radio emissions, believed to come from lightning discharges. However no visible lightning flashes were recorded [145]. Although no lightning was observed during Voyager flybys of Titan in 1980 and 1981, it was long suggested that lightning dischargers do take place on this moon of Saturn [146, 147]. However recent data from Cassini/Huygens seems to indicate that there is no lightning activity on Titan.

Modeling of SR parameters on the planets and moons of the Solar System is complicated by the lack of knowledge of the waveguide parameters. SR frequencies depend on the structure of the lower part of the ionosphere, which is not sufficiently studied. On Jupiter and Saturn the situation is yet more complicated. Little is known about the electrical parameters of the interior of Jupiter and Saturn. Even the question of what should serve as the lower waveguide boundary is a non-trivial one in the case of these gaseous planets. To our best knowledge there are no works dedicated to SR on Saturn. Up to date there was only one attempt to model Schumann resonances on Jupiter – in the [22]. Calculations yielded resonant frequencies of approximately 0.76, 1.35 and 1.93 Hz with quality factors of roughly 7, predicting sharp, pronounced peaks.

The situation with other planets is a little better. SR on Venus were studied by [19, 21]. Both studies, basing on different conductivity profiles and with different models yielded very close resonant frequencies: around 9, 16 and 23 Hz. The quality factors, though, differ substantially: [19] obtained Q-factors of ~5 while [21] acquired Q~10. Such a difference – by a factor of two, was predicted by [19] for more sophisticated ionosphere representations.

Martian global resonances were modeled by [21, 148, 149]. The results of the three studies are somewhat different. [148] obtained the resonant frequencies at about 13, 25 and 37 Hz with Q-factors around 3.5. The frequencies calculated by [21] are lower: 8.6, 16.3 and 24.4 Hz, with Q-factors of ~2.4. The disparity can probably be explained by the different models of Martian lower ionosphere used in the two studies. Nevertheless the low quality factors obtained in both studies show that pronounced sharp peaks at resonance frequencies should not be expected for the Mariner ELF waveguide. Significantly different results were obtained by [149], where several ionosphere models were used. The first resonance occurred at 11-12 Hz (depending on ionosphere model), the second and third resonances interfered to form a single peak at 21-25 Hz and the forth, fifth and sixth modes produced a very smooth-shaped peak at around 60 Hz.

The ionosphere of Titan is perhaps the most thoroughly modeled today. The recent interest in the largest satellite of Saturn is associated with the Cassini/Huygens Mission and expectations of finding evidence of lightning activity on Titan. Consequently, SR on Titan received more attention then resonances on other celestial bodies. The resonant frequencies obtained for various ionospheric conductivity profiles tested in studies by [150-152] range (for realistic models) from 11.0 to 15.0 Hz for the first mode, 21.2–
27.8 Hz for the second and 35.6–41.6 for the third. Unfortunately, the quality factors were not calculated in these studies. Comparable results were obtained by other authors: resonant frequencies of 19.9, 35.8 and 51.8 Hz with Q-factors of 1-3 were obtained by [153], and 11.8, 22.5 and 34.1 Hz with Q-factors of ~2 – by [21]. The low Q-factors acquired in these two studies show that the expected peaks, should lighting activity be found on Titan, are rather wide.

Schematic representation of Schumann resonances on Venus, Earth, Mars, Titan and Jupiter is shown on Figure 9. Today there is no possibility to validate SR parameters calculated for other planets and moons. The values of the resonance frequencies and quality-factors are very dependant on the ionospheric profile models. The accuracy of the latter is limited, and a deeper knowledge of planetary ionospheres would allow more precise predictions of Schumann resonance parameters. On the other hand, experimental evaluation of SR parameters can aid in the elaboration of the effective model of the ionospheric conductivity profile, and contribute substantially to the knowledge of lower ionospheres on planets of the Solar system.

![Figure 9: Schematic representation of Schumann resonances on Venus, Earth, Mars, Titan and Jupiter.](image)

9 SUMMARY

Being a global phenomenon, Schumann resonances have numerous applications in lightning research. Background SR records can serve as a convenient and a low-cost tool for global lightning activity monitoring. Q-bursts – large-amplitude excursions above the background level can be used to geolocate intense lightning strikes. These large-amplitude pulses are related to the occurrence of sprites and elves, which therefore can be tracked using SR records. Schumann resonances are one of the few tools which, through variations in global lightning activity, can provide continuous and long-term monitoring of such important global climate change parameters as surface temperature and upper tropospheric water vapor. An additional application of SR is extraterrestrial lightning research. Schumann resonances can be used to detect and, if necessary, monitor lightning activity on the planets and moons of the solar system.

There are still many open questions in SR research: importance of the day-night variation in the ionosphere conductivity profile, latitudinal changes in the Earth magnetic field, sudden ionospheric disturbances, polar cap absorption, accuracy of source geolocation, and determination of the spatial lightning distribution from the background records. Despite these open problems SR is one of the most promising tools in a variety of fields related to lightning research.

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